MAURY-SIMONDS
PHYSICAL
GEOGRAPHY

Richard Cambiano
726 So Second St
San Jose
California

Frontispiece

VESUVIUS

Eruption of April, 1906. Emission of gas, ashes, and sand as seen from the Observatory.

MAURY-SIMONDS PHYSICAL GEOGRAPHY

PHYSICAL GEOGRAPHY

BY

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REVISED AND LARGELY REWRITTEN

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NEW YORK .:. CINCINNATI .:. CHICAGO

AMERICAN BOOK COMPANY

MAURY-SIMONDS PHYS. GEOG.

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PREFACE

The advance of geographic science has been so great during the last decade that a thorough revision of the older text-books has become imperative. To the end that Maury's Physical Geography may maintain its position, it has been the writer's privilege not only to revise, but largely to rewrite that well-known book. In so doing an attempt has been made to preserve as far as possible the plan of the older work — a plan that has met the approval of a generation of teachers — and, at the same time, to modernize the text thoroughly.

In the matter of illustrations, the present volume will be found exceedingly attractive and the adoption of a smaller page will add much to the reader's comfort.

In the preparation of this edition, acknowledgments are due to many persons, especially to Dr. William J. Battle and Dr. William T. Mather of the University of Texas — the former, for the use of some of his excellent photographs of Egyptian scenery; the latter, for timely suggestions which have added materially to the accuracy of the text. Acknowledgments are also made to Mr. Sterling R. Fulmore for Hawaiian, Australian, and New Zealand views; to Professor A. J. Henry, of Washington, D.C., for cloud views; to Mr. W. E. Seright, of Stafford, Kansas, for the unique photograph of a tornado; to President D. S. Jordan, of Leland Stanford Junior University, for California earthquake views; and to Professor

H. L. Fairchild, of the University of Rochester, for photographs of drumlins, kames, and eskers. The diagrams and most of the maps have been drawn by the writer or, under his direction, by Mr. N. P. Pope.

FREDERIC W. SIMONDS.

THE UNIVERSITY OF TEXAS, AUSTIN.

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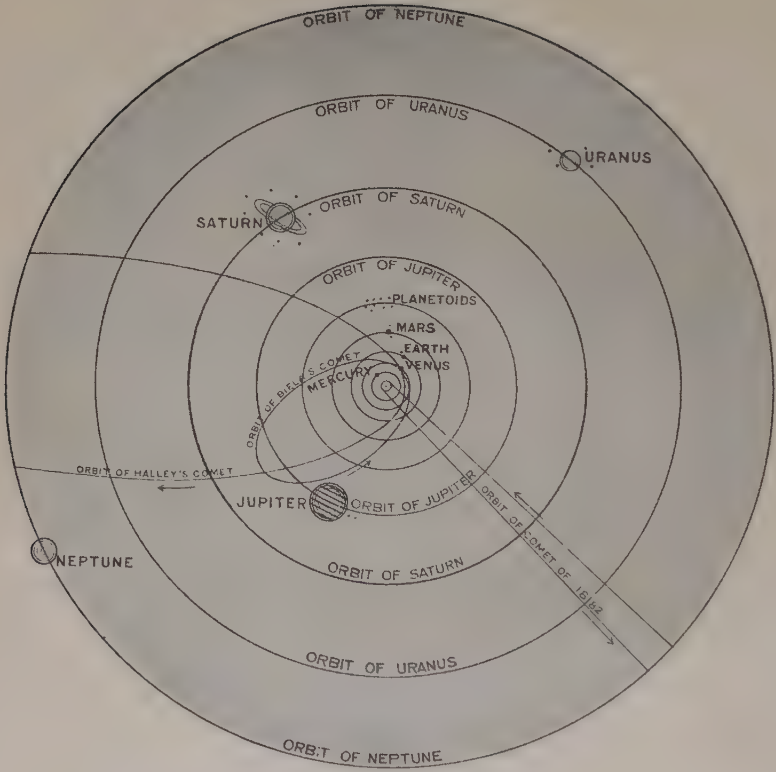
INTRODUCTORY

Physical Geography deals with the world in the present stage of its existence. It considers the machinery which makes day and night, seedtime and harvest; which lifts the vapor from the sea, forms clouds, and waters the earth; which clothes the land with verdure and cheers it with warmth, or covers it with snow and ice. Physical Geography, moreover, treats of the agents that cause the wonderful circulation of waters in the sea; that diversify the continents with mountains, hills, plains, and valleys, and embellish the landscape with rivers and lakes. It views the earth — its surface, its waters, and its enveloping atmosphere — as the scene of operation of great physical forces, which by their united action render possible the life of plants and animals; and studies the life of the globe, both terrestrial and aquatic, noting particularly the circumstances which are favorable or adverse to its development.

It has been found convenient to present the topics treated in the following order: —

I. The Earth.
II. The Land.
III. The Water.
IV. The Atmosphere.
V. Life.



THE SOLAR SYSTEM

PART I.—THE EARTH

I. THE EARTH AND THE SOLAR SYSTEM

The Solar System. — By the ancients the earth was regarded as the center of the universe. Men saw the sun in the same part of the heavens morning after morning, and when his light faded at night they saw the stars in nearly the same positions as on the preceding night. Hence they concluded that the sun and stars all move around the earth once in 24 hours. Careful observation seemed to confirm this idea. Astronomers watched the heavens; they mapped the stars; they recorded, from night to night, the places of the brightest among them. As a result, they found that the position of some remains unchanged with reference to that of their companions, while the position of others varies perceptibly.

The former were called *fixed stars;* the latter received the name *planets*, from a Greek word meaning *wanderers*. For several centuries, however, astronomers have known that the ancient idea was a mistake. The sun, not the earth, is the center around which the planets revolve, and the earth itself is a planet. The planets are not self-luminous, but shine by reflected sunlight. Their paths of motion, or orbits, are nearly circular, and they all journey around the sun in nearly the same plane. In their regular order, beginning with that nearest to the sun, the planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

With the exception of Mercury and Venus, they are attended by one or more moons, or satellites. The sun, planets, and satellites, together with a number of small planetary bodies

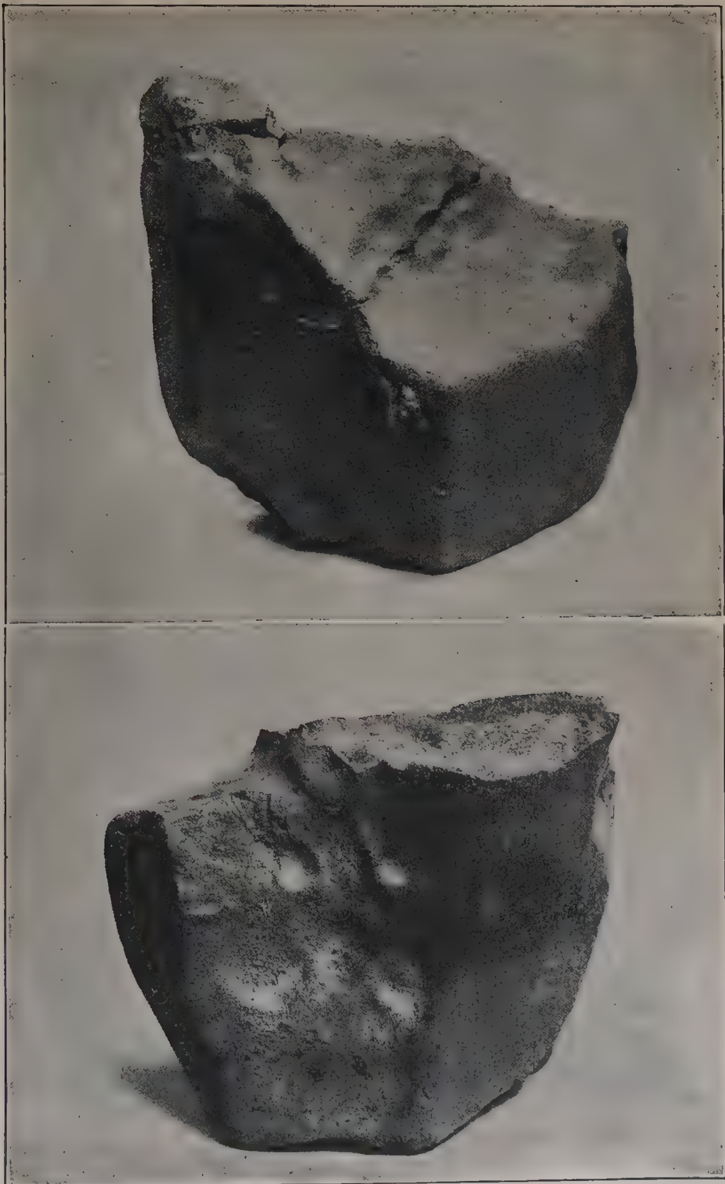
called *asteroids*, or *planetoids*, which revolve in paths between Mars and Jupiter, constitute the Solar System, so named from the Latin *sol*, the sun.

Within the limits of the Solar System there are also comets and meteoric swarms. The former are celestial bodies usually consisting of a head, with a very bright spot which gradually shades into a less luminous portion, or *coma*, and a tail, or streamer.

GIACOBINI'S COMET, DECEMBER 29, 1905
From photograph by Professor E. E. Barnard, Yerkes Observatory.

Owing to the movement of the camera, which was kept focused on the comet during the exposure, the stars appear as lines instead of points.

Comets seem to be composed of matter in a highly rarefied state, for even small stars are visible through them. Some, from their movements around the sun, must be considered members of the Solar System; others appear as casual visitors, passing never to return.



THE HENDERSON, NORTH CAROLINA, METEORITE

Two views. From proceedings of the U. S. Nat. Mus., Vol. 32.

The meteoric swarms seem, in some instances, to follow the orbits of certain comets; in others, the number of meteors is so great as apparently to fill the entire circuit of their own orbits. In either case, when they encounter the atmosphere of the earth, there is a brilliant display of shooting stars, the so-called meteoric showers.

The Sun. — The sun is also a star. From it the planets derive both heat and light. This vast ball, or sphere, is more than a million times as large as the earth. Were the earth placed at the sun's center, the latter body would reach so far into space as to extend nearly 200,000 miles beyond the orbit of the moon, or almost 440,000 miles beyond the earth's surface.

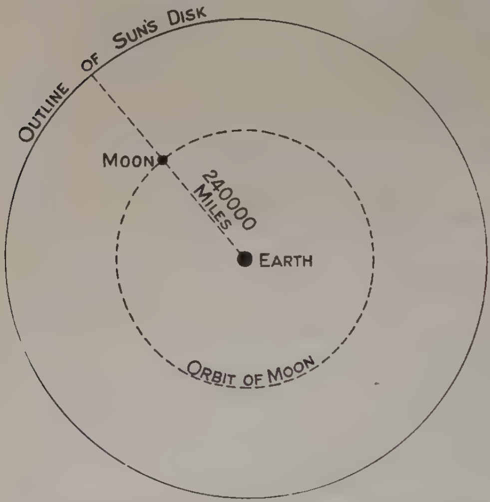
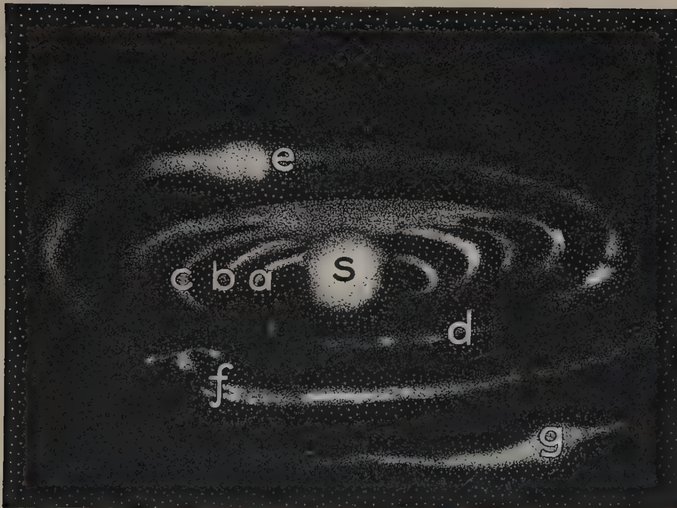


DIAGRAM SHOWING THE COMPARATIVE SIZES OF THE EARTH, THE ORBIT OF THE MOON, AND THE SUN'S DISK

The sun is in an intensely heated condition, and clouds of incandescent gases project outward from its surface for thousands of miles into space. From examinations made with the spectroscope it is known to contain many substances entering into the composition of the earth.

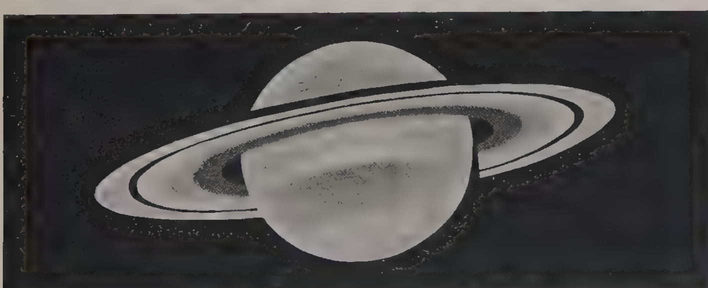
Origin of the Solar System. — The sun and the planets are composed of the same kinds of matter and have similar forms and motions. Many astronomers and philosophers have tried to combine these facts and others into an explanation of the origin of the Solar System. Such explanations are termed *hypotheses*. Of these hypotheses at least two merit attention; namely, the *nebular* and the *planetesimal*.



DIAGRAMMATIC ILLUSTRATION OF THE NEBULAR HYPOTHESIS

Showing the abandoned rings in various stages. *S* is the central sun; *a*, *b*, *c*, successive rings; *d*, *e*, *f*, *g*, denser portions of certain rings which, in the process of planet formation, are drawing the less dense portions within themselves.

The Nebular Hypothesis. — This hypothesis, which apparently fails to meet some of the necessary physical tests, assumes a vast glowing cloud, or *nebula*, of gaseous matter extending beyond



SATURN AND HIS RINGS

the orbit of the farthest planet and endowed with a slow rotary motion. As this nebula cooled and contracted, its rotation

became more rapid and it became disklike in form. As the contraction continued, partial or complete rings similar to the rings of Saturn were separated from the outer edge. These, contracting toward their densest parts, became planets, revolving around the central nucleus, which we call the sun.

The Planetesimal Hypothesis. — This hypothesis assumes the sun as the origin of the planets. Attracted by an approaching star, a sun wave of gaseous matter flew off forming, with the

RELATIVE SIZES OF THE SUN AND PLANETS

The names of the planets are indicated by their initial letters except Mercury and Mars which are indicated by *My* and *Ms* respectively.

central nucleus, a spiral nebula. This cooled and condensed into small separate particles (planetesimals) like the meteoric dust that sometimes falls upon the earth. Some of these particles,

colliding and uniting, formed small bodies, which were enlarged by continual showers of planetesimals and thus became planets.

The Relative Sizes of the Sun and Planets. — The relative sizes of the sun and planets are shown in the cut on page 16, in which the diameter of the sun has been reduced to 3½ inches. It has been calculated that the sun contains 600 times the united volumes of all the bodies revolving about it. Even the larger planets are greatly inferior to it in size, while the smaller planets are comparatively insignificant.

If the earth be represented by a globe one foot in diameter, the sun must be represented by a sphere 35 yards in diameter, placed 2¼ miles from the globe, in order to show in proper proportion the size of the two bodies and the distance between them. In a similar manner Jupiter, the largest planet, would be represented by a globe 3½ yards in diameter at the distance of 11 miles from the sun.

The Earth and the Universe. — From the astronomer we learn that most of the fixed stars are possibly the suns of other systems resembling our own, but in many cases vastly larger. From him we also learn that the heavens are filled with unknown numbers of such systems. Hence follows the conclusion not only that the earth is one of the smaller members of the solar system but that the solar system is itself one of the numerous systems that fill the immensity of space. With this in mind it is possible to realize that *the earth is an exceedingly small part of the created universe.*

The subordinate position of the Solar System is strongly suggested by the fact that, under the influence of the other suns of the universe, it appears to be moving through space in the direction of the constellation Hercules.

II. THE SHAPE, SIZE, AND DENSITY OF THE EARTH

Shape of the Earth. — As inhabitants of the earth we are greatly impressed with its surface irregularities. What a contrast between lofty summits of the Andes or Himalaya mountains

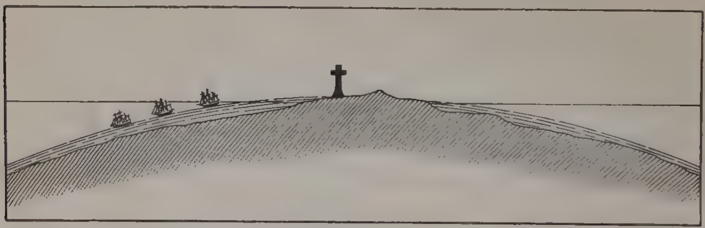


DIAGRAM ILLUSTRATING THE CURVATURE OF THE EARTH

and the depths of the ocean basins! Can a body exhibiting so many and so great inequalities fall within the boundary

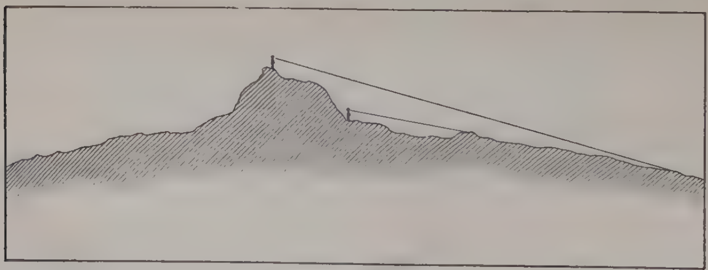


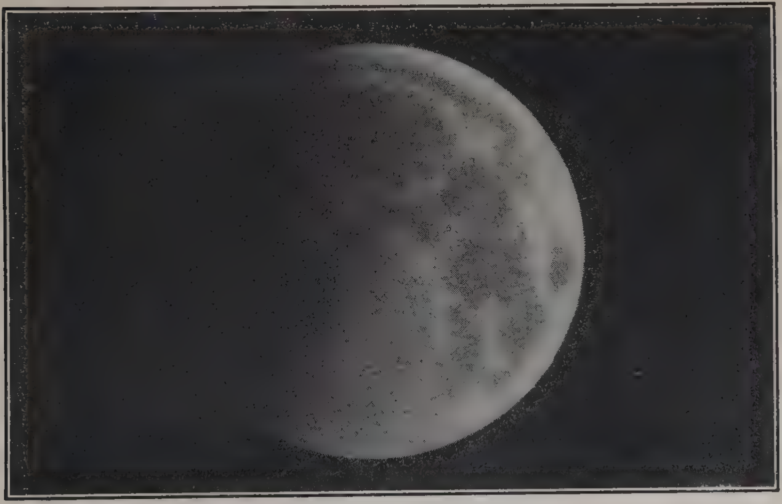
DIAGRAM ILLUSTRATING THE CURVATURE OF THE EARTH BY THE INCREASED RANGE OF VISION IN ASCENDING A HEIGHT

of a regular geometric form? We are merely suffering from the nearness of the view. Could we station ourselves on the

moon, then as we beheld the earth, its surface irregularities would no longer confuse us. In comparison with the whole they would sink into insignificance, and the earth would appear as a great rounded globe or sphere not varying in its general shape from the other planets.

There is ample proof that the surface of the earth is curved.

1. Watch ships as they sail seaward. Do they not pass over a curved surface as their hulls, then their sails, and lastly their topmasts, disappear from view?



AN ECLIPSE OF THE MOON

From photograph by G. W. Ritchey, Yerkes Observatory.

Partial phase of the total eclipse of October 16, 1902, 10:33 P.M. The margin of the earth's shadow is curved.

2. Stand at the foot of a hill overlooking a plain and note the boundary line or limit of vision. Now climb to the summit and note the increased range of vision. Were the earth flat, this would not occur.

3. Observe the curved margin of the earth's shadow during an eclipse of the moon.

The sun, earth, and moon being now in the same straight line, the shadow of the earth extends in the form of an elongated cone far beyond the orbit of the moon. That body, in the course of its movement, cuts this shadow which

obscures its face. While the margin of the shadow is ill defined, it is, nevertheless, sufficient to show the general curvature of the surface.

That the earth is of a spherical shape is also shown —

1. By voyages and journeys "round the world."
2. By the measurement of arcs of great circles.
3. By the fact that the horizon when viewed from a high point rising above a level plain, as from a tower or the summit of a hill, is always circular, a property belonging only to spherical bodies.

The Earth an Oblate Spheroid. — The particles of a rotating body tend to fly off in straight lines. This tendency is called centrifugal force. Gravitation tends to make a mass spherical. These two forces combined have caused the earth, which is somewhat plastic and elastic, to assume a slightly flattened spherical form called an oblate spheroid. Its longest diameter is nearly 7927 miles and its shortest diameter nearly 7900 miles. Its greatest circumference is about 24,900 miles, its smallest circumference about 24,860 miles, and the area of its surface 197 millions of square miles.

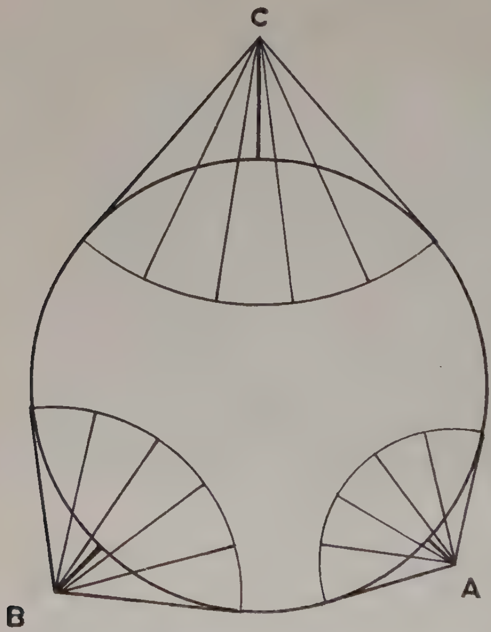


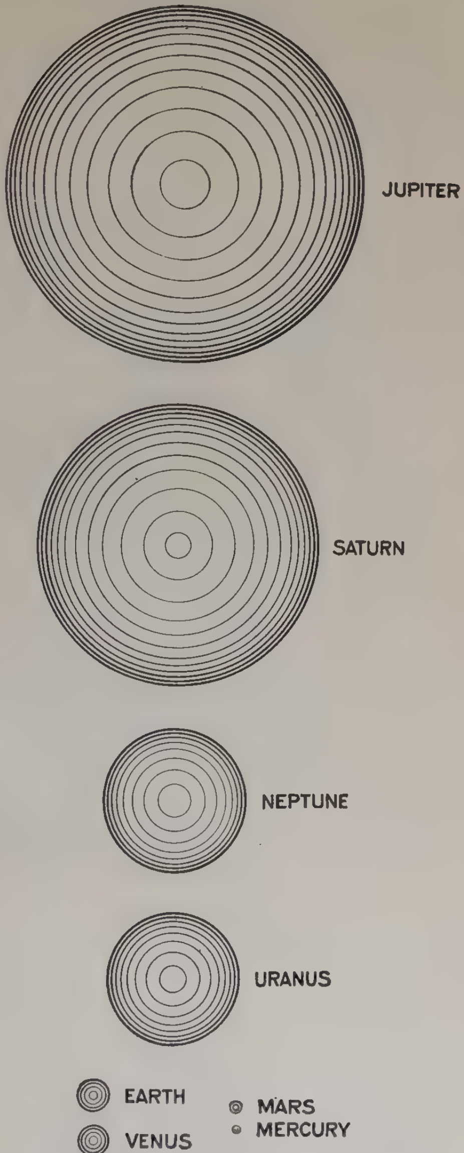
Diagram for demonstrating the Spheroidal Form of the Earth

The horizon when viewed from a high point, A, B, or C, is a circle

The oblateness of the earth is shown by the fact that although the weight of a body on its surface is nearly constant, it is slightly greater in high latitudes.

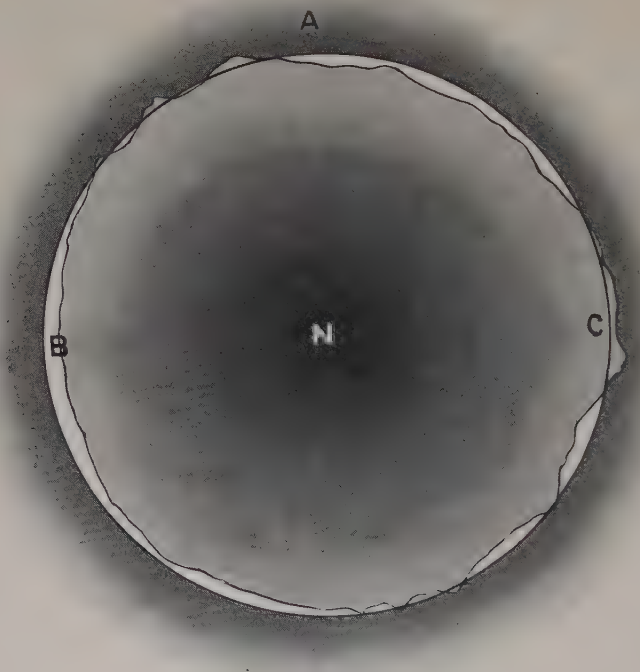
Density of the Earth. — The exterior is the only part of the earth concerning which we have definite knowledge. Here we encounter matter in its three forms: the gaseous, represented by the atmosphere; the liquid, represented by the hydrosphere, or water areas; and the solid, represented by the lithosphere, or "crust." These spheres are arranged in the order of their densities, and although the air and water are often spoken of as the earth's coverings, they are as much of the planet as the lithosphere.

On account of pressure each of these spheres should become denser in the direction toward the center of the earth. The bottom of the atmosphere, especially that part resting on the sea, is densest, as it is compressed by the weight



THE PLANETS ARRANGED ACCORDING TO SIZE

of the air above it. Similarly, the water in the deepest parts of the sea should be densest, but water is practically a non-compressible medium. It does not seem unreasonable that the materials constituting the lithosphere should increase in density



SECTION OF THE EARTH

A, atmosphere; B, hydrosphere; C, lithosphere; N, nucleus.

toward the earth's nucleus or centrosphere, which must be the densest part of all. That such is the fact appears to be proved by numerous experiments which go to show that while the density of the outer portion of the lithosphere is about 2.5, that of the lithosphere and nucleus together is not far from 5.5.

III. THE MOTIONS OF THE EARTH

Effects of the Earth's Motions. — The earth has two motions which greatly influence all things living upon it, whether animals or plants. The first is a daily motion, or rotation on its *axis*, by which there is produced an alternation of light and darkness called day and night. The second is a yearly motion, or revolution about the sun, by which seasonal changes are produced and the many consequences flowing from them.

Meridians. — When the sun reaches its highest point for the day, the shadow cast by a plumb line extends north and south. Hence north-and-south lines are called *meridians*, or midday lines. All meridians when produced meet at the ends of the earth's axis, called the poles. The meridian of any place can be determined roughly by means of a vertical rod on a level table. Beginning about half an hour before midday, mark at intervals of two minutes the end of the shadow cast by the rod till the shadow lengthens. The line from the end of the shortest shadow to the base of the rod points north and south and lies in the meridian of the place.

Parallels. — Lines at right angles to any meridian extend east and west. Since they are parallel circles around the earth, they are called *parallels*. The parallel midway between the poles is called the *equator*, since it divides the earth into two equal parts, or hemispheres.

Position. — The position of a place is determined when we know its distance north or south of the equator and its distance east or west of a standard meridian.

Latitude and Longitude. — The distance north or south from the equator, measured in degrees along a meridian, is called *latitude*. The latitude of the equator is 0°, and of the poles

90°, the highest latitude. Distance east or west from a standard meridian measured in degrees along a parallel is called *longitude.* The meridian of Greenwich, near London, is commonly taken as the standard. The longitude of the Greenwich meridian is 0°, and the longitude of the most distant meridian is 180°. The sun crosses all meridians, that is, 360° of longitude, every 24 hours, at the rate of 15° an hour. Hence the difference in longitude between two places is equal to 15° multiplied by the difference in time in hours. The difference in time can be determined by means of accurate timekeepers commonly called chronometers, and by telegraph. The length of a degree of longitude is about 68.7 miles at the equator and decreases gradually to 0 at the poles.

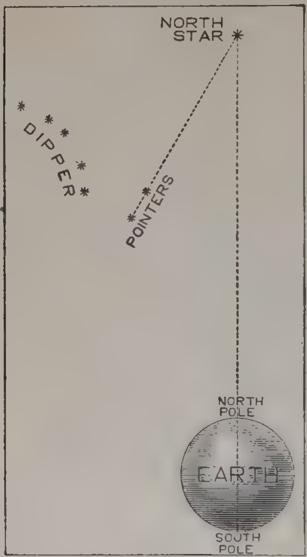


DIAGRAM SHOWING THE POSITION OF THE NORTH STAR IN THE HEAVENS

Measuring Latitude.— The line of the earth's axis passes close to a star in the northern heavens called the North Star or the polestar. To an observer at the equator, the polestar seems to be at the horizon. As he travels northward it seems to rise in the heavens a degree for every degree of latitude till at the pole, 90° N., it is in the *zenith*, or 90° above the horizon. In other words, the latitude of a place north of the equator may be found by measuring the altitude of the polestar.

At the equinoxes (see p. 26) the sun is directly over the equator, and on these dates the latitude of a place is equal to the angular distance from the zenith to the midday sun.

The Problem of Eratosthenes. — In 240 B.C. Eratosthenes, a famous Greek astronomer, measured an arc of a meridian by means of the noon shadow. He found that the angular differ-

ence between the sun's altitude at Syene, in Egypt, and its altitude at Alexandria, 5000 stadia north of Syene, was 7° 12′. On this basis he computed the earth's circumference to be 250,000 stadia, or about 24,000 miles.

Rotation. — The sun always illumines the half of the earth turned toward it, leaving the other half in darkness. Owing, however, to the rotation of the earth once in 24 hours, all points upon its surface, with the exception of limited areas near the poles, are during that period brought alternately into sunlight (day) and immersed in darkness (night).

The earth rotates from west to east. In consequence of this a point on its surface, as New York, crosses the boundary between the darkened and lighted hemispheres, or the great circle of illumination, and the sun is seen to rise in the east. An hour later the same phenomenon is observed by the people of Saint Louis, and two hours later by the people of Denver. In each of these places the sun appears to rise higher and higher in the heavens until the meridian or midday point has been reached, and then it begins to recede toward the western horizon, and finally disappears or sets. As the sun rises in New York an hour before its appearance in Saint Louis it likewise sets in New York an hour earlier, and for a similar reason it sets in New York two hours earlier than in Denver.

An interesting evidence of the earth's rotation is that suggested by Newton. It is easy to see that a body at the top of a tower will, if the earth really rotates, move with greater velocity than will the base of the tower. Let a ball be dropped from the top of such a tower, and, if not deflected by the air, it will strike a point on the ground some distance from the foundation. The experiment is of little practical value, for it is difficult to calculate the deflection caused by the air.

Revolution. — The passage of the earth around the sun, or its revolution, requires $365\frac{1}{4}$ days. This constitutes the time interval known as a year. The path of the earth around the sun is not a perfect circle, but an ellipse having the sun in one of its foci. While the axis of the earth constantly points in the same direction whatever may be its position in its orbit, it is inclined to the plane of that orbit $66\frac{1}{2}°$, or $23\frac{1}{2}°$ from the perpendicular. To this is due the varying lengths of day and night and the changes of the seasons.

The nearer a planet is to the sun, the more rapidly it revolves, and the shorter is its year. The year of Mercury, the nearest planet, is only 88 days long; Jupiter's year consists of about 12 of ours; Neptune's of more than 160.

Variations in the Lengths of Day and Night.— Let *S* represent the sun (see diagram) and the arrows the direction of the earth's motion in its orbit. When the earth is at *A* it will be seen that

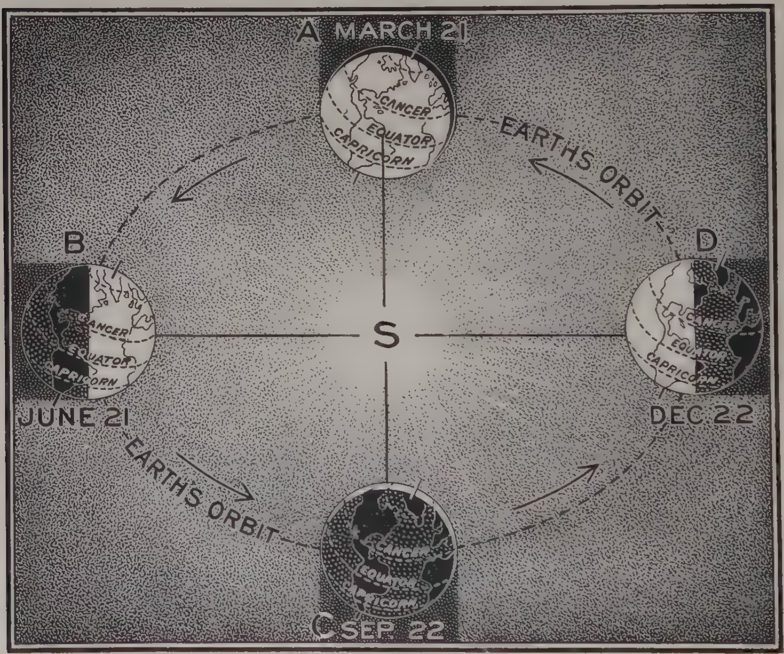


DIAGRAM SHOWING THE POSITION OF THE EARTH AT FOUR POINTS IN ITS ORBIT

A, the vernal equinox; *B*, the summer solstice; *C*, the autumnal equinox; *D*, the winter solstice.

the direct rays of the sun fall upon the equator and that the great circle of illumination passes exactly through the poles. Day and night in all parts of the world are therefore equal. This occurs on March 21, which is called the *vernal equinox*. The earth, continuing its passage around the sun, reaches the position

B in its orbit. The direction and inclination of its axis remaining the same, it will be seen that the direct rays of the sun have *apparently* moved north and that they now fall upon the Tropic of Cancer. Moreover, as the sun always illumines one half of the earth, the entire region within the arctic circle is in daylight, while the corresponding region within the antarctic circle is in darkness; that is, during the passage of the earth from *A* to *B* the great circle of illumination has changed its position so that instead of passing through the poles it now passes through two alternate points $23\frac{1}{2}°$ from the poles.

As the great circle of illumination passes beyond the north pole, the days in the northern hemisphere constantly increase in length, until at *B*, the summer solstice, or June 22, there is experienced the longest day and the shortest night of the year. On the other hand, in the southern hemisphere the opposite conditions prevail. During the passage of the earth from *A* to *B* the days grow constantly shorter, and the nights longer; thus in the two hemispheres there is an alternation in the lengths of the periods of light and darkness.

At *C* the sun's rays fall again directly upon the equator, the great circle of illumination passes through the poles, and the days and nights are equal. This is the *autumnal equinox*, or September 22.

At *D* the direct sun rays fall upon the Tropic of Capricorn, and the great circle of illumination reaches only the arctic circle, but in the southern hemisphere sunlight extends beyond the pole to the antarctic circle. It will be seen that the conditions which prevailed when the earth was at *B* are completely reversed. Then the northern hemisphere experienced its longest day and its shortest night, now the southern hemisphere has its longest period of light and its shortest period of darkness. This is the *winter solstice*, or December 22.

The length of days and nights varies with the latitude. At the equator, or 0°, they are always equal; that is, twelve hours long. At latitude 30.8° the longest day is 14 hours; at latitude 58.5°, 18 hours; at latitude 63.4°, 20 hours; at latitude 66.5°, 24 hours. Within the arctic or antarctic circles the longest

day or greatest period of sunlight exceeds 24 hours, being in latitude 67.4°, 1 month; in latitude 73.7°, 3 months; in latitude 90°, 6 months.

The arctic day and the arctic night have been thus described by an eye-witness: —

"The sun moves quickly in these latitudes from the first day he peers over the horizon in the south until he circles round the heavens all day and all night; but still quicker do his movements seem when he is on the downward path in autumn. Before you know where you are he has disappeared and the crushing darkness of the arctic night surrounds you once more.

"On September 12 we should have seen the midnight sun for the last time if it had been clear and no later than October 8 we caught the last glimpse of the sun's rim at midday. Then we plunged into the longest Arctic night any human beings have ever lived through in about 85 north latitude. Henceforth there was nothing that could be called daylight, and by October 26 there was scarcely any perceptible difference between day and night." — Report of Captain Otto Sverdrup, Appendix to *Nansen's Farthest North*.

Sidereal and Solar Days. — It is the rotation of the earth on its axis that gives rise to the time divisions in common use. The time of a rotation of the earth can be measured accurately by means of the stars, and is called a *sidereal day*, from the Latin *sidus*, a star. It is the time unit used by astronomers. The time between two successive noons is called an *apparent solar day*. As the earth rotates it moves onward in its path around the sun, faster as it approaches the sun, and slower as it recedes. Hence apparent solar days are somewhat longer than sidereal days, and vary slightly in length. The average length of apparent solar days is called a *mean solar day* and is the common unit of time. It is divided into two series of 12 hours each, one beginning at midnight and the other at noon.

Standard Time. — Before the advent of railroads and the telegraph each community used the mean solar time of its own meridian. As communication between distant points became frequent and rapid, it became necessary to have a simpler time system. Hence, in 1883, the railroads agreed to use a system of standard time. By this plan the United States is divided into four time sections, each of which uses the mean solar time of its standard meridian. These meridians are 15° apart and their times are an hour apart.

The Julian and the Gregorian Calendars. — The earth revolves around the sun in about 11 minutes less than $365\frac{1}{4}$ days. Hence a calendar year of 365 days is shorter than the solar year. In order to make the calendar year more accurate, Julius Cæsar in 46 B.C. decreed that each fourth year (leap year) should contain 366 days. This correction was too great, and in 1582 the error amounted to nearly half a month. In that year Pope Gregory XIII partially corrected the error by suppressing 10 days in the calendar. He also made a rule which keeps the calendar practically correct. By this rule every year of which the number is divisible by 4 without a remainder is a leap year excepting years divisible by 100, which are leap years only when divisible by 400. Thus 1600 was a leap year; 1700, 1800, and 1900 were common years; 2000 will be a leap year; and so on. The Gregorian calendar, or New Style, was not adopted in England till 1752, when Parliament enacted that the day following September 2 of that year should be called September 14.

Change of Seasons. — As already shown (page 26), when the earth is at *A* sunshine extends from pole to pole, and day and night are of equal length everywhere in the world. As the direct rays of the sun at this time fall upon the equator, the heat there is of the greatest intensity, decreasing polewards in the two hemispheres as the inclination at which they strike the surface increases. This is illustrated on page 30. Let *A*, *B*, and *C* represent three sunbeams or rays striking the earth in three different places. On account of the remoteness of the sun they are practically parallel, but owing to the curvature of the earth they are cut by its surface at different angles. The beam *A* falling upon the equator warms an area equal to its cross section; the beam *B* falling in a latitude north of the equator warms an area of greater size than its cross section, hence a diminished temperature; the beam *C* striking the earth at a higher latitude warms a still greater area, but with a further diminution of temperature. There is, moreover, a loss in the heating power of the sun's rays occasioned by their passage through the atmos-

phere — the more inclined the rays, the greater becomes the atmospheric distance to be traversed and the greater the loss of heat. (Compare the atmospheric distances traversed by the beams *A* and *B*.)

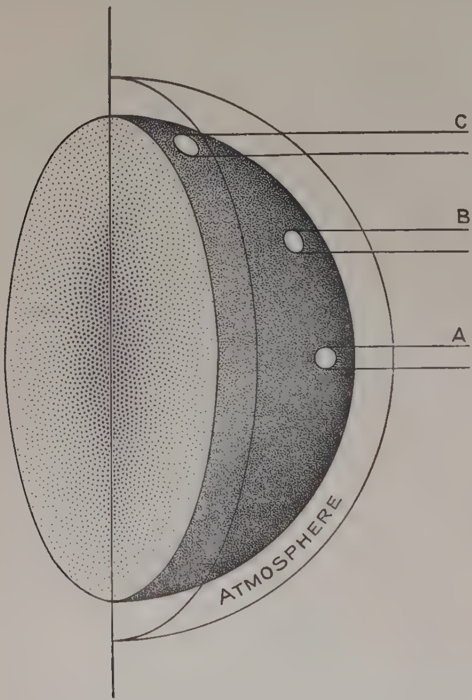


DIAGRAM ILLUSTRATING THE MANNER IN WHICH THE SUN'S RAYS PENETRATE THE ATMOSPHERE AND STRIKE UPON THE EARTH'S SURFACE IN DIFFERENT LATITUDES

The warming of the earth when in the position *A* (page 26) produces the conditions known as spring in the northern hemisphere and autumn in the southern. As the earth advances in its orbit toward *B*, on account of the inclination of its axis toward the sun, the direct rays or beams steadily move toward the north until at *B* they fall $23\frac{1}{2}°$ north of the equator. *The Tropic of Cancer is therefore the northern limit of the direct sun rays.*

With the increased length of day in the northern hemisphere, which has already been explained, comes an increase of heat and those conditions known as summer, while, on the other hand, the diminution of heat effects, due to the presence of the direct sun rays north of the equator and the shortening of the day, produce in the southern hemisphere the cold or winter season.

As the earth moves toward the position *C* in its orbit, the direct rays of the sun recede from the Tropic of Cancer, the

northern hemisphere gradually cools until the conditions at *A* are repeated; that is, day and night are of equal length, the direct rays fall upon the equator, and neither hemisphere is favored at the expense of the other. Thus in the northern hemisphere the summer season passes into autumn, while in the southern the wintry days have given way to those of spring.

When the earth has reached the point *D* in its orbit, the pole is inclined away from the sun, and the direct beams having moved south of the equator now fall $23\frac{1}{2}°$ south of that great circle. *The Tropic of Capricorn is therefore the southern limit of the direct sun rays.* The summer of the southern hemisphere has arrived and the northern hemisphere has entered upon the winter season.

IV. TERRESTRIAL MAGNETISM

Magnetism of the Earth. — To the earth as a whole belong certain properties of a magneto-electric character, not yet fully understood, which are the source of much scientific interest as well as of great practical value. The importance of the discovery of magnetism and the invention of the compass can scarcely be estimated. Without that instrument navigation would be practically impossible and the determination of direction over wide areas of the earth's surface futile. While magnetism falls more properly within the domain of physics, the fact that the earth acts as a weak magnet suffices also to bring that subject within the scope of physical geography.

Magnetism. — Among the ores of iron there is a variety of the mineral magnetite known as lodestone, which possesses the power of attracting to itself filings or other small pieces of iron. Such a body is called a *magnet*, and the influence that it exerts over other bodies is called *magnetism*. If a needle or a bar of steel be rubbed with lodestone, this property of the *natural magnet* will be imparted to it, and the needle or bar of steel becomes an *artificial magnet*. The property of magnetism also appears in a bar of soft iron or steel forming the core of an insulated coil of copper wire through which an electric current is passed, but with the cessation of the current the magnetic property disappears. Such a temporary magnet is termed an *electro-magnet*.

Polarity. — If a bar magnet or a horseshoe magnet be placed beneath a sheet of paper upon which iron filings have been sprinkled and the paper gently tapped, the iron particles will arrange themselves about the extremities of the magnet in the greatest abundance, leaving the shape of the magnet well outlined upon the paper. The extremities of the magnet, where

the attraction is greatest, are termed the *poles*, and the area through which the magnetic influence is felt, the *magnetic field*. A comparison of the effects of each pole upon the filings would apparently lead to the conclusion that the two poles are identical, but a simple experiment will serve to show that they are different.

Let two common needles be magnetized and each suspended by a thread attached to its middle point by a bit of wax. These needles will tend to arrange themselves in a north-and-south direction. If their north ends or poles be marked and made to approach each other, it will be found that between them there is exerted a repellent force; likewise, that between the south ends of the needles there is also repulsion. On the other hand, it may be readily shown that between the north pole of one needle and the south pole of the other there exists an attractive force. The general law governing this phenomenon is as follows: *Like poles repel, unlike poles attract.*

About halfway between the north and south poles, along a line crossing the magnet, the opposite magnetic forces are neutralized. This is known as the *neutral line.*

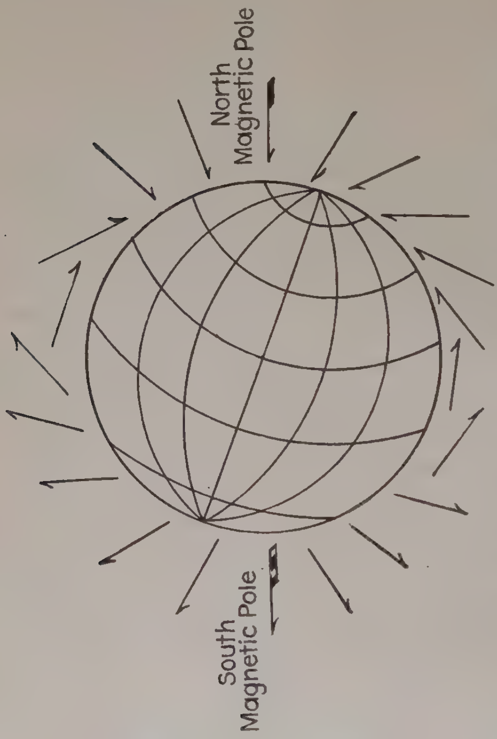
If a piece of iron, or a magnetic needle, be suspended exactly over this line, it will not be attracted at all. On either side of it, however, a suspended needle is drawn toward one or other of the poles. The *exact* position of the neutral line depends on the relative strength of the poles. As these are seldom if ever of equal strength, the neutral line will rarely or never be equidistant from both.

The Earth a Magnet. — In some very important respects the earth behaves like a magnet.

In the first place it displays *attractive power* precisely similar to that of the magnet. It is terrestrial magnetism which causes magnets to point northward when suspended.

Secondly, like the magnet, the earth has *magnetic poles.* These are not exactly at the north and south geographical poles, but at some distance from them. They are the points at which the needle stands vertical. The north magnetic pole is in North

America. It is situated in Boothia, latitude 70° 5′ north, longitude 96° 45′ west. The discovery of this pole was made by Sir James Ross in 1831.



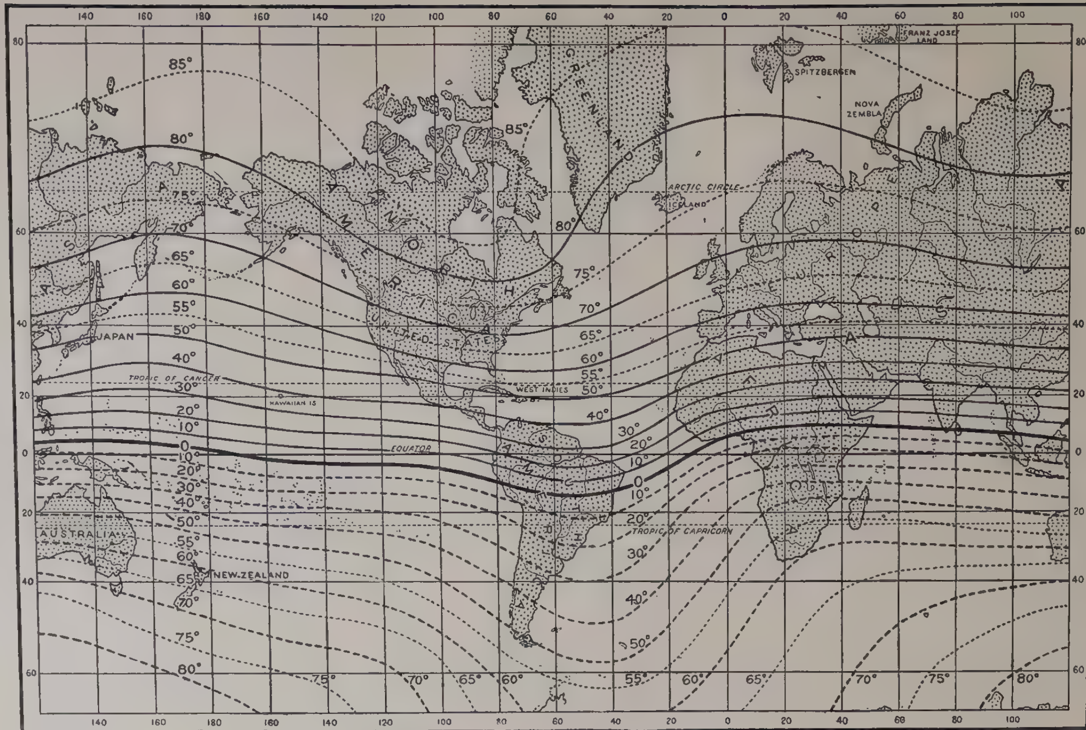
THE EARTH AS A MAGNET

The vertical arrow at the left of the north geographic pole points to the *north magnetic pole*. The vertical arrow at the right of the south geographic pole points from the *south magnetic pole* (which is in the hemisphere turned from the reader and therefore not directly opposite the north magnetic pole).

The position of the south magnetic pole has not been so accurately determined. Sir James Ross reached a point in the Antarctic Ocean where the inclination was 88° 35′, from which its situation has been computed. It is not, however, diametrically opposite the north magnetic pole, but far to one side. It lies in the vicinity of lat. 75° S., long. 138° E. The positions of these poles are constantly changing.

Thirdly, the earth, like a magnet, has a *neutral line*. This line encircles the globe about midway between the north and south magnetic poles. Along it the opposite polar forces counteract each other. It is called the *magnetic equator*. Its course is traced upon the chart.

Inclination or Dip of the Needle. — In passing northward from the magnetic equator the north end of the needle is drawn downward more and more from a horizontal position until the north magnetic pole is reached, where, as already stated, it points vertically. In like manner, in going southward from



Lines of Equal Magnetic Dip for 1905

the magnetic equator, the needle is drawn downward until at the south magnetic pole it should again point vertically, although reversed in position. (On page 34 the needle is represented in the form of an arrow. At the north magnetic pole the head of the arrow is directed downward; at the south magnetic pole, the shaft.)

Inclination, or dip, may be represented on a chart by drawing lines in the northern and southern hemispheres connecting all points in which the *angle of dip* is of the same value.

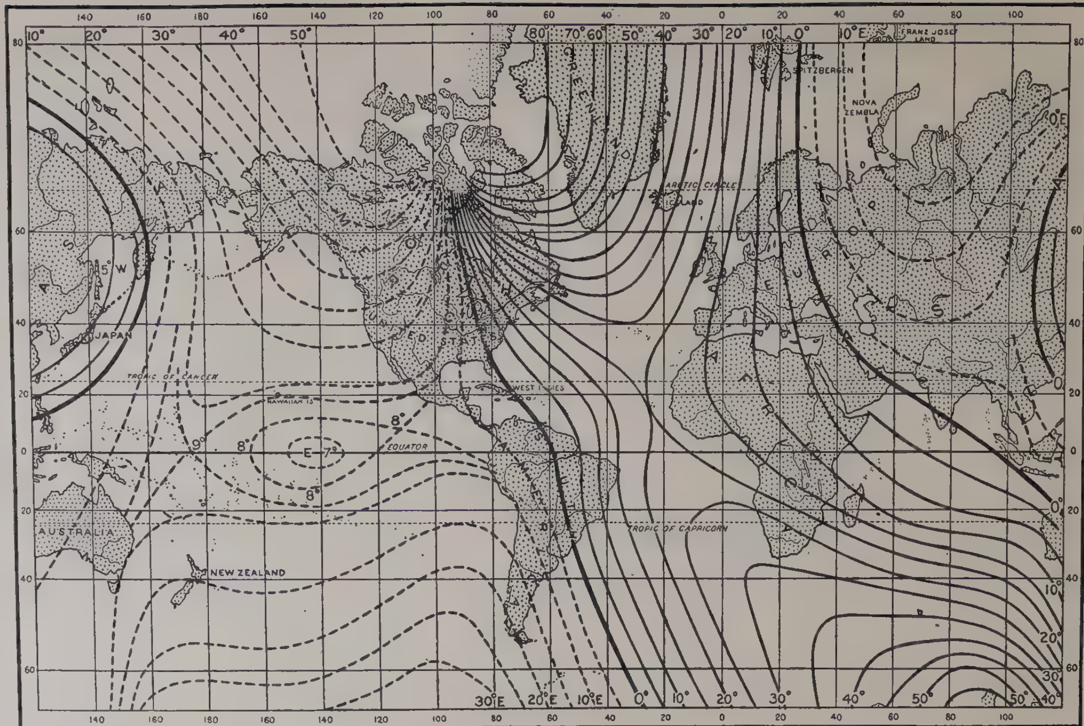
Such lines are usually termed *isoclinic lines*, but by some authors they have been called *magnetic parallels*. The line connecting points having no dip is, of course, the *magnetic equator*. In the eastern hemisphere it lies to the north of the geographic equator, but in the western, for the most part, to the south.

Declination of the Needle. — While magnets free to move assume a north-and-south direction, they do not point exactly to the true geographical north, but a little to the west or the east of it. The deviation from the true northerly position is called the *declination* of the needle.

The direction in some places is east, in others west. It will be seen from the map that over about one half of the globe it is easterly, over the other half westerly.

The amount of declination varies in different localities, being much greater in some than in others. This may be presented to the eye in two ways: First, by drawing on the same chart both the true and the magnetic meridians. The latter have been defined as "the lines along which one would travel were he to set out at any place on the earth and always follow the compass needle." As the magnetic poles, through which the magnetic meridians pass, do not coincide with the geographic poles of the earth, a greater or less variation in the two sets of meridians is inevitable.

Second, by drawing lines on a chart passing through those places having the same declination. Such lines, called *isogonic*



LINES OF EQUAL MAGNETIC DECLINATION FOR 1905

Full lines indicate west magnetic declination, and broken lines east magnetic declination.

lines, must not be confused with the magnetic meridians. Just as there is a magnetic equator along which there is no dip or horizontal deviation, so there are lines, known as *agonic lines*, along which there is no declination. On the accompanying chart (page 37) both the isogonic and the agonic lines are shown. In the western hemisphere the agonic line, passing from the north magnetic pole southeastward through Hudson Bay and Canada, enters the United States near the eastern end of Lake Superior, and, after traversing the intervening states in a general southeast direction, leaves the country not far below the city of Charleston in South Carolina. Eastward of this line the declination is to the west; westward of this line the declination is to the east. This is indicated on the chart by the use of broken and unbroken lines.

Variations in Declination.— The intensity and position of the forces which cause the needle to deviate from the true north-and-south direction are constantly changing. Hence arise what are known as variations in declination.

Secular variations extend over long periods. The declination at London was east in 1580, and amounted to 11° 15′; in 1657 it was zero; in 1818 it attained its maximum, 24° 38′ 25″, and was west. In 1877 it had decreased to 19° 22′ 22″ west. It is therefore decreasing at the rate of about 5′ annually; so that in about 200 years it should be east again.

Diurnal variations also occur. They are eastward and westward oscillations of the needle, caused every day by the sun. The extreme eastward deflection is reached at about 8 A.M., the westward at about 2 P.M. The movements observed at the same hour in the northern and southern hemispheres are opposite in direction.

Diurnal variation is almost zero at the equator. In the northern hemisphere it is greatest at the time of the summer solstice, least at the winter solstice.

Magnetic Storms. — To certain "spasmodic variations" in the earth's magnetism, which are plainly indicated by the behavior of the needle, the term *magnetic storms* has been applied. Their duration may vary from a moment to several days. Often they are attended by electrical display such as auroras. While their coming seems to be somewhat irregular, a relation

has been noticed between these disturbances and solar activity — that for those years in which the sun spots are most numerous magnetic storms are most frequent and of greatest violence. The "spot period" of the sun is a little over eleven years, from minimum to maximum, say five years; from maximum to minimum, six years.

"In November, 1882, near the period of maximum sun spots, a magnetic storm occurred which caused the magnetic needle at Los Angeles, Cal., to move over $1\frac{1}{3}°$ out of its normal position. There was at the time a brilliant auroral display. The storm occurred over the entire earth, at Los Angeles, Toronto, London, St. Petersburg, Bombay, Hongkong and Melbourne, and began practically at the same instant of absolute time." — L. A. BAUER.

General Conclusion.— The phenomena above described show conclusively that the earth is a great though rather feeble magnet. But whether its magnetism results from magnetic bodies located within its mass (permanent magnetism), or, as some have thought, from the generation of electric currents, due to its unequal heating during rotation (electro-magnetism), is not yet fully determined.

"All modern investigations would seem to lead to the conclusion that there exists both a very deep-seated magnetic field and one confined to a comparatively thin layer, and that the earth's total magnetism results from systems of electric currents as well as from permanent and induced magnetizations."

— L. A. BAUER.

V. INTERNAL HEAT OF THE EARTH

Evidences of Internal Heat. — While the surface temperature of the earth's crust ranges from about 80° Fahrenheit at the equator to possibly 0° F. at the poles, there are good reasons for believing that the earth's interior is intensely hot. As bearing upon this subject the evidence furnished by deep mines, hot springs, geysers and artesian wells, and volcanoes will be considered.

Mines. — In his search for mineral wealth man has penetrated far into the earth's crust. In many parts of the world his operations have been carried on by means of deep shafts, and in no instance has he failed to note an increase of temperature for an increase of depth below the surface. A comparison of observations made in widely separated localities shows that the rate of increase is not altogether uniform, but varies with the conductivity, or power to transmit heat, of the rocks encountered, and is, moreover, modified by local conditions, as proximity to a volcano or a mass of igneous rock not yet thoroughly cooled.

Omitting exceptional cases, the average rate of increase, for depth below the line unaffected by surface heat or cold (line of no variation), seems to be 1° F. for about 65 feet.

In boring the Saint Gothard tunnel, between Italy and Switzerland, the temperature increased at the rate of 1° F. for 82 feet, and in boring the Mont Cenis tunnel, between Italy and France, at the rate of 1° F. for 79 feet.

As illustrating the extremes of variability two unusual cases may be cited. As the result of careful observation at the celebrated Calumet-Hecla copper mine on the south shore of Lake Superior, it has been found that for the depth of 4939 feet the average increase of temperature is 1° F. for 103 feet.

On the other hand, unusually high temperatures have been experienced at the Comstock lode, Virginia City, Nev., as, for example, 130° F. at the depth of 2000 feet or an increase of 1° F. for 15.4 feet of descent, and at the Gold Hill mines on the same lode waters entered the 3000-foot level at a

temperature of 170° F., which would give an average of 1° F. for 28 feet. These high temperatures may be due to the decomposition of rocks containing feldspar.

Artesian Wells bear testimony to the same rapid increase of heat. These have been sunk in various parts of Europe and America to a depth varying from 1000 to 4000 feet.

The rate of increase in the temperature varies in different places. The average is 1° F. for 50 to 70 feet. The temperature of the well at Grenelle, near Paris, is 81.7° F. Its depth is 1798 feet. That at Budapest is 3160 feet deep. Its temperature is 178° F. It supplies a part of the city with warm water. An artesian well at Marlin, Tex., 3330 feet in depth, has a temperature of 147° F.

Experience shows that by boring artesian wells, warm water may be obtained in almost every region of the earth.

Hot Springs. — Hot or *thermal* springs occur in all parts of the world. While more abundant in volcanic regions, they are by no means confined to the vicinity of volcanoes. The thermal springs of Bath, England, having a mean temperature of 120°, are 900 miles from the Icelandic volcanoes, over 1000 miles from Vesuvius and Etna, and fully 400 miles from the extinct volcanic region of France.

As to the source of the heat manifested by hot springs there is reason to believe in many instances that it is local, as in the case of springs occurring in regions of active and extinct volcanoes. There are, however, thermal springs, breaking out along the line of deep fissures, in which the source must be regarded as "deep-seated," and there are still other cases in which chemical action may be urged as the source of heat. Hot springs, it seems, afford evidence of the existence of subterranean heat, but they furnish meager data for establishing its rate of increase for depths below the surface.

On the Island of Saint Michael, one of the Azores, there are some remarkable hot springs. Here the waters rising through volcanic rocks become charged with silica (the substance of quartz), which, upon reaching the surface, on account of cooling, they precipitate, or deposit, in the form of sinter. As these

waters act as a petrifying medium, grasses, ferns, and other forms of vegetation are seen about the basins in various stages of mineralization.

An excellent example of the deposit of carbonate of lime is afforded by the terraces of Mammoth Hot Springs, Yellowstone National Park. It is thought that the precipitation here may in part be due to the action of algæ (low forms of plant life), to which also may be attributed the brilliant colorings, scarlet, blue, green, noticed upon freshly forming surfaces.

Geysers. — The term *geysers* or *gushers* is applied to certain periodically eruptive hot springs occurring in limited areas in

MINERVA TERRACE, A HOT SPRING DEPOSIT, YELLOWSTONE NATIONAL PARK

The substance of this beautiful terrace is travertine or carbonate of lime. By its deposition from hot waters numerous basins have been built up which now contain pools of various temperatures. From photograph by Haynes.

regions of active or dying volcanic energy. The most noted are those of the Yellowstone National Park in northwestern Wyoming, Iceland, and New Zealand.

The distinguishing characteristic of a geyser is an eruption during which hot water and steam are ejected with more or less violence from a craterlike opening or basin which is connected below with a pipe or conduit leading downward into the earth. The water is heated to a high temperature; that of the Great Geyser in Iceland is 212° F. at the surface, but in the lower

portion of the tube the thermometer indicates 266°. By the relief of pressure, due to the overflow of the basin, the superheated waters rising toward the surface suddenly flash into steam, thus producing an explosion or eruption by which a column of water and steam is projected far above the vent.

Like ordinary hot springs, geysers afford evidence of the existence of heat below the earth's surface, but the source of the heat is evidently volcanic.

About the mouths of geysers there are often found highly ornamental incrustations, consisting of silica and other minerals which are soluble in the geyser water while it is hot, but are deposited as it cools. The basins or craters vary in size from a few inches to many feet in diameter and height. That of the Great Geyser in Iceland is four feet in depth and 72 feet in diameter. In the center of this basin is a pipe or funnel eight feet wide. Out of this funnel water nearly boiling constantly issues. Eruptive discharges also occur. Of these there are certain premonitions. Underground rumblings are heard, the water in the basin boils furiously, and a domelike mass of hot water with clouds of steam is thrown 40 or 50 feet high.

One or more of these minor discharges occur, and then succeeds a grand eruption. With a rumbling that shakes the ground, another column of boiling water 90 to 100 feet high is forced into the air with loud explosions and amid clouds of steam. Then out through the top of this column smaller jets are driven to marvelous heights above it. The pipe is thus emptied of water. But at once it begins to fill up, only to be emptied again by another grand explosion.

Of the Yellowstone geysers an observer says: —

"Of all the geysers whose eruptions we witnessed, the Grand was, I think, the most interesting. It played each evening at a regular hour. Suddenly it shot a vast stream of water over 200 feet into the air. This was maintained for a few minutes; then it ceased, and the waters shrank back into the cavernous hollow below. Meanwhile subterranean thunder shook the ground, and after a minute's cessation another eruption occurred."

Volcanoes are the most striking of all manifestations of the earth's internal heat. They are so important that they will be considered in detail in a subsequent lesson. Here, however, it is proper to observe what strong confirmation they afford to the theory of subterranean heat. Streams of lava, white-hot, like molten iron, issue through their craters from the interior of

A Geyser in Eruption

"Old Faithful," Yellowstone National Park. This celebrated geyser received its name from the regularity of its eruptions, which occur at intervals averaging 65 minutes. The discharge lasts five or six minutes, the column of steam and water reaching the height of 90 to 100 feet. From photograph by Haynes.

the earth, together with steam and other heated vapors, hot ashes, and stones.

Condition of the Interior of the Earth. — The phenomena above considered have suggested the conclusion that the interior of the earth is in a fluid state and that only to the depth of from 30 to 40 miles is the crust of the earth solid.

It is argued that if the heat increase for depths below the surface at the rate noted in mines and deep borings, then at a comparatively shallow depth even the most refractory substances must necessarily be in a state of fusion. This view, it will be observed, is in accord with the nebular hypothesis.

Most scientific men, however, doubt the fluidity of the central mass, and admit the existence only of local reservoirs of molten rock. They contend that, instead of being fluid, the interior of the earth, though intensely hot, is pasty, or even solid. In support of this they argue that the enormous pressure exerted upon the interior of the earth would nullify the effect of its internal heat; for if a substance be subjected to pressure, it cannot melt so readily as under ordinary conditions. A body, therefore, may remain solid at a very high temperature, if under pressure.* In consequence of this the state of the successive layers constituting the earth is such that while they are subjected to a heat which increases enormously as the center is approached, they are at the same time subjected to a *pressure* which also increases enormously as the center is approached.

Whether, however, we adopt the view that the central mass is fluid or solid, it does not affect the conclusion that it is in an intensely heated condition.

* This is applicable to substances which contract when they solidify; ice and a few other substances, which expand upon solidification, have their melting points lowered by pressure.

VI. VOLCANOES

What is a Volcano? — To this question there are two answers: The first is that of the geographer; the second, that of the geologist.

(1) The term *volcano* is usually applied to a mound, hill, or mountain composed of rocky materials ("lava," "cinders," "ashes," etc.) ejected from the earth's interior through a tube or opening in the crust. The upper end of this conduit is in a bowl-shaped depression, called a *crater*, which may be on the summit or slope of the ejected mass. As typical volcanoes are ordinarily more or less conical, it is customary to speak of volcanic cones.

(2) But as defined by Professor Judd, volcanoes are not necessarily "mountains" at all. "Essentially they are just the reverse — namely, holes in the earth's crust, or outer portion, by means of which communication is kept up between the surface and the interior of our globe."

Kilauea, on an island of the Hawaiian group in the North Pacific Ocean, on account of the great size of its crater, is one of the most remarkable volcanoes of the world. Its external opening, on the flanks of Mauna Loa, is in the form of a basin nearly 1000 feet deep. This great crater has a width of two miles, a length of three miles, and a circumference of eight miles.

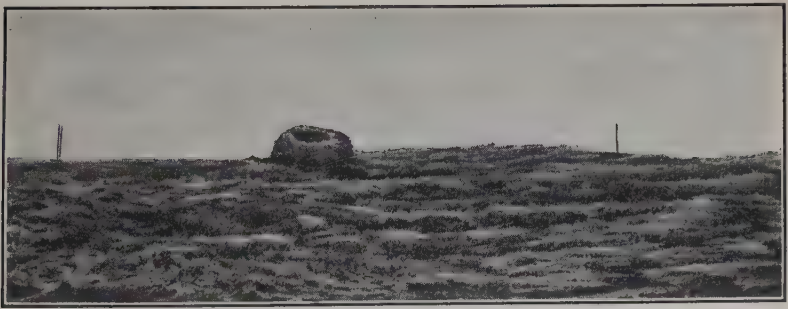
Formation of Volcanic Cones. — If at its beginning a volcano is simply a hole in the earth's crust, the form assumed by the cone will depend very much upon the character of the material ejected. Should it be in a very liquid state, like melted glass or iron, then the cone will rise at a low angle from a spreading base as seen in the Hawaiian volcanoes. Should, however, the material be viscous, like pitch, the cone will rise at a steeper angle and will assume somewhat of a dome shape. Again,

should the material ejected be fragmental, as ashes and cinders, the cone will rise at a rather high angle and take on the form seen in Cotopaxi and Chimborazo. The inclination or slope of a mixed cone, that consisting of both molten and fragmental materials ejected from the same vent, will, in large degree, depend upon the kind of material predominating, being steeper for the fragmental and less steep for the molten.

Submarine Volcanoes. — The formation of a volcano may begin at considerable depths below the level of the sea. In proof of this it may be said that vast numbers of oceanic islands owe their existence to volcanic action, and deep-sea soundings show that many of the deepest parts of the ocean are covered with volcanic débris.

In 1831 a mass of matter accompanied by a discharge of steam rose from the sea near the coast of Sicily, and attained in a few weeks the height of 200 feet above the water. It had a circumference of about three miles and was named Graham Island. In a few months, however, it disappeared, as the materials composing it, being loosely held together, were unable to withstand the action of the waves.

Height of Volcanic Cones. — Volcanic cones vary much in height. Some are but slightly elevated, less than 500 feet;



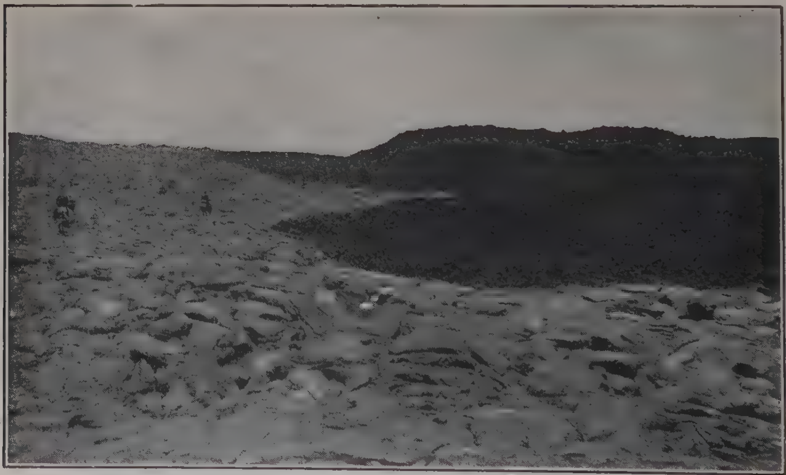
SMALL CONE NEAR OUTER RIM OF MAUNA LOA

others tower skyward many thousand feet. The latter do not attain this great height through the accumulation of ejected matter alone, but are usually situated in highly elevated plateau or mountainous regions, as is conspicuously shown in the case

of the higher volcanoes of the Andes. Here are cones like Aconcagua, in Argentina, and Chimborazo, in Equador, attaining

MAUNA KEA, THE HIGHEST MOUNTAIN IN THE PACIFIC (13,805 feet)

an elevation of over 20,000 feet. Mount Vesuvius, the best-known volcano of the world, has an altitude of about 4000 feet, while Mauna Kea, in the Hawaiian Islands, reaches 13,805 feet.



LAVA FLOWS ON MAUNA LOA
Smooth lava, known as pahoehoe, on the left; granular lava on the right.

Volcanic Products. — The materials ejected from volcanoes are steam and other gases, lava, stones, ash, sand, and dust.

Of all the vapors given off during an eruption steam is by

far the most abundant. This when chilled hovers above the vent in the form of a great cloud which upon further condensation falls as rain. The steam discharge is especially violent during an eruption of the explosive type. Steam and other volatile substances often escape from fissures and minor vents,

LAVA CASCADE, KILAUEA

within the crater, called *fumaroles*, as well as from external fissures and even from flowing lava.

Of the volcanic gases the following may be mentioned: hydrochloric acid, sulphureted hydrogen, sulphurous acid, and carbon dioxide.

To the molten product of volcanic action the term *lava* has

been applied. In its consistency and appearance it is subject to a wide range. It may be thin and free flowing when erupted, or it may be ropy and viscid; it may be highly charged with steam or other vapor, which expanding imparts a cellular structure, or it may be rather compact; it may be very light colored or it may be very dark — ranging from almost white through gray, brown, and even red, to black. In general it has the appearance of slag as seen about a smelting furnace.

An exceedingly cellular form of lava, the consolidated froth, forms what is known as *pumice* or pumice stone. Often lava is reduced to fragments so fine as to form *dust* or *ash;* or, if the particles are coarser, *volcanic sand.* Again, molten lava, of the highly liquid variety, is sometimes, either by the action of escaping steam or by the blowing of the wind, drawn out into long, delicate fibers, like spun glass, called by the native Hawaiians "Pele's hair" in honor of the goddess of Kilauea.

Volcanoes Classified. — Volcanoes may be classified as active, dormant, or extinct. *Active* volcanoes eject various substances. When no signs of activity are given for a considerable time, the volcano is said to be *dormant.* When a volcano has been dormant for centuries, and it seems probable that its activity is lost forever, it is said to be *extinct.*

The frequency of volcanic discharges is varied. Some volcanoes are continuously active. Stromboli has been for 2000 years in a state of constant but not dangerous activity. It is visible at night in every direction for the distance of more than 100 miles. A red glow is seen from time to time above the summit of the mountain due to the illumination of the vapor cloud by the red-hot lava in the crater. This becomes gradually more and more brilliant, and then as gradually dies away. It is this phenomenon which has given to Stromboli the name "Lighthouse of the Mediterranean."

On the other hand, Cotopaxi has been in eruption only seven times in 100 years.

Vesuvius exhibits great irregularity. It had been long dormant previous to the eruption of A.D. 79, and the steep walls of its crater were covered with

vines and other vegetation. Cities and villages graced its slopes. After this eruption, none of great moment occurred until 1631. At that time, one of the most destructive on record took place. It continued for three months, and destroyed a number of cities and villages. The last eruption occurred in April, 1906.

From these and similar facts it is evident that we have no knowledge of any law which governs the frequency of volcanic eruptions.

Eruptions. — The character of volcanic eruptions is, in a great measure, dependent upon the nature of the materials

VESUVIUS IN ERUPTION, APRIL 5, 1906

A dense column of steam and ashes is rising from the crater. The steam below the summit is from a recent lava flow. See also Frontispiece.

ejected. The emission of great bodies of steam and other gases is productive of an eruption of an *explosive* type, which is usually accompanied by a discharge of fragmentary matter of various kinds, such as dust, ash, and even blocks of lava. On the other hand, when the emission consists mainly of molten lava, the

eruption is less violent, or of the *quiet* type. Many of the best-known volcanoes discharge matter in the gaseous, liquid, and solid forms, their eruptions being of a *mixed* type.

Eruptions are usually preceded by subterranean rumblings and tremors. Before the great eruption of 1872, Vesuvius gave indications of unusual activity for a whole year. In many cases, however, the eruption follows the warning immediately. An eyewitness, writing of Stromboli, says that he had observed numerous light, curling wreaths of vapor ascending from the crater, then suddenly, without the slightest warning, a sound was heard like that of a locomotive giving off steam; and the eruption at once occurred.

In general, after the preliminary rumblings and tremors, dense columns and globular masses of *watery vapor* mingled with a variety of gaseous substances issue from the crater. According to the state of the atmosphere, and the existence of winds and air currents, the vapor assumes a variety of forms.

In the case of Mount Vesuvius it not unfrequently expands after attaining a certain height, and becomes like a vast "umbrella," as the Italians call it, having a top many miles in circumference. The lurid glare of the boiling lava in the crater below is reflected upon the under surface of the umbrella, and gives the appearance of a vast conflagration. This spectacle is indescribably impressive at night. During a great eruption of Vesuvius, vapor, it is said, rose to the height of 20,000 feet, or nearly four miles.

The steam emitted, being condensed, falls as rain. This rainfall is excessive and long continued, and often gives rise to destructive floods. Around the vapory column vivid lightning constantly plays.

Jets of steam under high pressure, if allowed to issue from an orifice, give rise, in doing so, to large quantities of electricity. A machine has been constructed to generate electricity in this way. From it torrents of sparks as much as 14 inches in length have been obtained. The crater, with its immense volume of uprising vapor, may be compared to a gigantic machine of this description.

Often with the vapor are mingled immense quantities of volcanic *ashes and sand,* which descend and cover the surrounding country, sometimes to the depth of many feet.

Over 1800 years ago (A.D. 79), the cities of Herculaneum and Pompeii in Italy were covered with a deluge of ashes from an eruption of Vesuvius. They were buried from 70

FUJI, A VOLCANIC PEAK, JAPAN
The highest mountain in Japan (altitude about 12,400 ft.).

to 120 feet, and lost to view for nearly seventeen centuries. In 1713, a well digger turned up a bit of statuary, which led to the discovery of the two cities. The work of exhuming them is still going on.

The distance to which the ashes of a volcano may be carried is almost incredible. In 1845, the ashes of Hecla were carried to the Orkney Islands, a distance of nearly 700 miles, and in 1815, those of Tomboro, in the island of Sumbawa, fell at Benkulen, 1100 miles away.

In August, 1883, during an explosive eruption on the island of Krakatoa, situated in the Straits of Sunda, an immense volume of dust amounting to 4½ cubic miles was suddenly hurled upward into the atmosphere. This great dust cloud attained a probable height of 17,000 feet, and so fine were its component particles that they remained suspended for many months in the upper air, giving rise, it is thought, to an interesting optical phenomenon known as the "red sunsets."

During the disastrous outbreak of Mont Pelée, on the island of Martinique, in May, 1902, an immense quantity of superheated steam and acid vapor charged with *incandescent lava fragments*, in the form of dust, sand, and stones, rolled down the mountain side, destroying almost instantly the town of Saint Pierre and its 30,000 inhabitants.

The Emission of Lava in the molten state is the most imposing of volcanic phenomena. The action which goes on has been compared to that which occurs in a pot of boiling porridge.

As the mass of porridge is heated, steam is generated at the bottom. This rises through the porridge. In doing so it forces a portion upward. More and more steam being generated, bubbles of porridge rise to the surface, and mimic explosions occur, or the porridge is thrown in little jets above the surface of the boiling material. The process may increase in violence until the phenomenon of boiling-over takes place. Quite similarly the boiling lava is forced upward higher and higher in its crater by vast volumes of steam that are seeking to escape. Explosions occur on the boiling surface, and often jets are thrown far into the air.

Finally, the rising lava overflows the rim of the crater, or quite as often bursts through the sides of the mountain, and pours down its slopes in rivers of fire.

So numerous were the fissures which rent Vesuvius in the eruption of 1872 that liquid lava seemed to ooze from every portion of it, and, as an eyewitness expressed it, "Vesuvius sweated fire."

Lava streams vary in magnitude. The largest recorded were those of Skaptar Jökul, in Iceland, in the years 1783–85. Torrents of molten rock deluged the island. River courses, ravines, and lakes were filled, and the surface of the country for hundreds of square miles was completely devastated. Some of the streams were about 50 miles in length, and in certain places

15 miles in breadth, and 100 feet deep. In some of the narrow valleys the depth was 600 feet.

The velocity of the streams, and the distance to which they reach, depend on the fluidity of the lava and the slope of the land. One thousand feet per hour is a rapid rate; the extreme of 10,000 feet per hour has been observed, though rarely.

The retention of its heat by a lava stream is very remarkable. When the surface of the stream has cooled, it becomes a hard crust which prevents the rapid escape of the heat.

A mass of lava 500 feet thick, ejected from Jorullo in 1759, was seen smoking by Alexander von Humboldt 45 years after. The Indians lit cigars at its crevices. The lava thrown from Vesuvius in 1858 continued as late as 1873 to give out steam, and remained so hot that one's hand could not be held in some of the fissures for more than a few seconds.

The flow of the lava is the beginning of the end. After its occurrence the showers of ashes gradually cease, the explosions become less and less frequent, and at length no evidence of volcanic activity remains, save perhaps a vapor cloud veiling the summit of the mountain.

Distribution of Volcanoes. — Two significant facts are to be observed regarding the distribution of volcanoes.

First: The active volcanoes of the globe are, as a rule, situated upon areas which are undergoing upheaval. Those portions of the surface of the earth which are subsiding are without volcanic activity.

Second: Almost all volcanoes are near the sea. Those upon the continents are close to the shores. The only well-authenticated examples of volcanoes situated far inland are those of Ararat and Demavend, of Peshan and Turfan, or Hot-Scheou, and the Solfatara of Urumtsi, all in Central Asia.

The most striking exemplification of this law of volcanic distribution is presented by the Pacific Ocean. It is literally encircled with active volcanoes.

There are three great belts traversing the globe, within which nearly all the volcanoes of the world are situated. These may be called the Pacific Insular Belt, the Atlantic Insular Belt, and the American Continental Belt. (See map on p. 57.)

The Pacific Insular Belt extends along the northern and western shores of the Pacific Ocean. Beginning with the Aleutian Islands it embraces Kamchatka, the Kuril, Japanese, and Philippine Islands, Sumatra, Java, New Guinea, the Tonga Islands, and New Zealand.

One extension of this belt embraces the Society, Marquesas, and Sandwich or Hawaiian Islands; another is the volcanic region of Victoria Land.

The Atlantic Insular Belt comprises extinct and active volcanoes and volcanic islands which traverse the Atlantic from north to south. The islands of Jan Mayen, Iceland, the Azores, Cape Verde Islands, Saint Helena, and Tristan da Cunha are points which mark this volcanic band.

The American Continental Belt extends from Cape Horn and the South Shetland Islands to Alaska, a distance of more than 10,000 miles. All along this line volcanoes, singly or in groups, are found. An outlying spur of it includes the Lesser Antilles.

A minor yet very important volcanic belt is that of the Mediterranean region. It comprises Etna, Vesuvius, Stromboli, and Vulcano in the Lipari Islands, and Santorini and Nisyros in the Ægean Sea.

Outside of the three great belts there are many volcanoes irregularly distributed. In the Pacific all islands not of coral origin are composed of volcanic rocks. In the Indian Ocean there are volcanoes upon Madagascar and the adjacent islands.

In central France, in Spain, and generally throughout Europe, there are numberless proofs of volcanic action. The volcanoes most remarkable for the irregularity of their situation are those in Central Asia already mentioned.

The number of active volcanoes on the surface of the globe is estimated at from 300 to 350. Of dormant and extinct about 1000 are reckoned.

Volcanoes of the Malay Archipelago. — No other region in the world is so thickly studded with volcanic cones as that of the Malay Archipelago, of which Java is the center. On that island alone they number between 20 and 30. Their discharge, how-

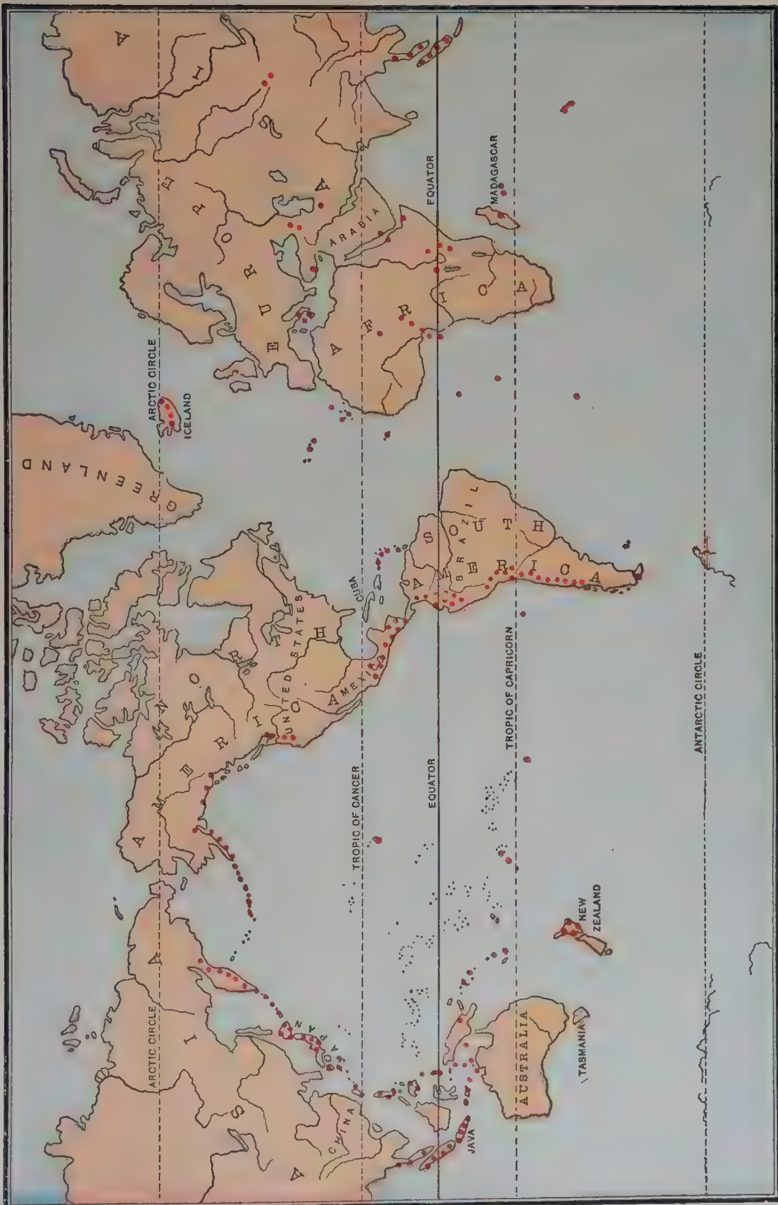


CHART SHOWING THE DISTRIBUTION OF VOLCANOES

ever, is not usually lava, but sulphurous vapors, acid waters, and mud. Occasionally in this region there are eruptions of the explosive type on a stupendous scale, as that of Papandayang, Java, in 1772, Tomboro, Sumbawa, in 1815, and on the island of Krakatoa in 1883.

During the famous eruption of Papandayang its cone lost 4000 feet of height. Previous to that event it was the loftiest volcano in Java, having an altitude of 9000 feet. At the time of the eruption it was thought that this great cone had been engulfed and a vast area of land, amounting to 90 square miles, swallowed up, including 40 villages. Later investigations have shown that the top of the cone was undoubtedly destroyed by an explosion, not dissimilar to that of Krakatoa, and that the villages were buried beneath the vast mass of dust, sand, and scoria blown from the summit.

In 1815, Tomboro, on the island of Sumbawa, 200 miles from Java, burst forth with such violence that the explosions were heard at the distance of 970 miles.

Causes of Volcanic Action. — The fundamental cause of volcanic action is undoubtedly the expansive force of compressed steam and other gases. Two cases are conceivable: The compressed steam and gases may be free, that is, not blended with the lava; or they may be imprisoned within the substance of the lava. The force developed will be the same in either case, but the mode of action will be different.

1. *The action of free gases.* — We have already seen that at a comparatively shallow depth the earth is intensely hot and that water readily finds its way through crevices in rocks or between the strata. Should this water, or a portion of it, come in contact with heated matter, the effect will be to convert it into steam. This may be done with great suddenness. Then conditions would arise such as cause the explosion of steam boilers.

A careless engineer allows the water in his boiler to get low, but still keeps up the fire. Into the intensely heated boiler he admits water, which is now converted into steam with such rapidity and in such quantity that it cannot possibly escape. The boiler is unable to resist the pressure, and an explosion takes place.

Water that finds its way into the heated subterranean regions of the earth may be suddenly converted into steam. The re-

sult is an eruption of the explosive type and the liberation of vast quantities of water vapor, dust, sand, and other fragmentary products.

2. *The action of absorbed gases.* — The second case, in all probability, occurs more commonly than the first, and, in fact, seems to offer a possible explanation for most of the phenomena of a volcanic eruption.

A number of substances, solid and liquid, absorb, under pressure and at high temperatures, steam and other gases. Lava is one of these. If thus charged the lava in a volcanic conduit should be relieved of pressure by the overflow at the vent, its capacity for retaining the gases in absorption would be diminished. They would expand and force the lava in whatever may be the direction of least resistance precisely as the volume of gases liberated from gunpowder and similar substances expands and forces obstacles before it with explosive violence.

Among other things this satisfactorily explains the pulverization of lava and the production of volcanic sand and ashes. The gases absorbed by the lava being relieved from pressure blow it into powder, as wood is blown to pulp for making paper.

Some writers consider that volcanoes are due to the shrinkage of the crust of the earth compressing and forcing upward molten matter from subterranean regions.

It has also been suggested that the extrusion of the lighter lavas may be due to the sinking of the more condensed or heavier rock above under the influence of gravity. This would explain the quiet welling out of lava in some volcanic eruptions, especially fissure eruptions. Steam, however, is admitted to be the only agency which accounts for the explosive character of eruptions.

VII. EARTHQUAKES

An Earthquake is the shaking or trembling of the crust of the earth due to the transmission of a jar, shock, or impulse — in the form of earth waves — which has its origin below the surface. It may be nothing more than a slight tremor similar to that produced by the passage of a heavily loaded wagon along the street, or it may be a movement of such violence as to overthrow and destroy whole cities.

Earthquakes are usually preceded by a rumbling noise, like distant thunder, then the ground rises and falls, houses rock to and fro until they are rent from top to bottom or fall with a crash into ruins. In some cases the earth opens with gaping cracks which either close again or are permanent. In a few seconds a city may be demolished and hundreds of its inhabitants dead or dying.

Earth waves, like sound waves, are elastic waves. From their origin, known as the *centrum* or *focus*, they spread through the crust in all directions. Although usually regarded as a point, the focus is probably, in most instances, a *fissure of displacement* or *fault*. Its depth below the surface is believed rarely to exceed 10 or 15 miles, and oftentimes it may be less.

If the materials of the crust were of the same composition, temperature, and density throughout, earth waves would pass outward from the focus in spherical shells of alternate compression and rarefaction, and the *surface waves*, or visible waves, would be the outcroppings of spherical waves which spread in circles from a point directly over the centrum, known as the *epicentrum*, as shown in the accompanying diagram.

There is, however, reason for believing that earth waves are ellipsoidal rather than spherical, on account of their accelerated

velocity in the deeper and more elastic portions of the earth's crust, and, further, that the centrum occupies one focus of the ellipsoid.

Owing to the different materials encountered and the varying conditions affecting elasticity, an earthquake must be regarded as a very complicated earth movement in which the

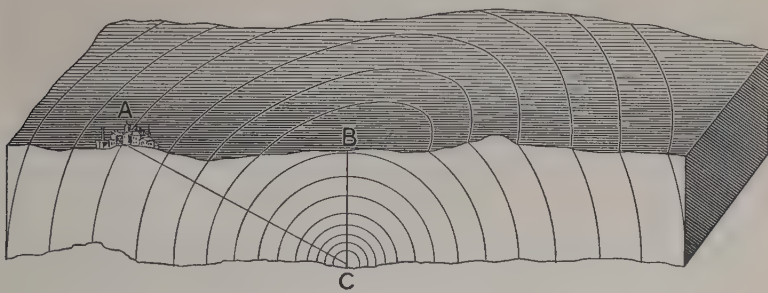


DIAGRAM ILLUSTRATING THE PROPAGATION OF EARTH WAVES

C, the focus or centrum; *B*, the epicentrum or point on the surface where the shock is vertical; *A*, point on the surface where the shock may be destructive, as here the oscillation contains two elements, the horizontal as well as the vertical. It should be noted that, if the crust block is homogeneous throughout, the surface waves, which are the outcropping spherical waves, spread in ever increasing circles from the point *B*.

waves are subject to many and intricate deviations from their theoretical shape, whether spherical or ellipsoidal.

The velocity of earth waves varies, depending upon the intensity of the shock, the nature of the media through which they pass, and the distance from the centrum, or point of origin.

The wave velocity of the well-known Charleston earthquake of August, 1886, was found to be about 190 miles per minute; that of the Japanese earthquake of October, 1891, about 78 miles per minute. Although the speed of earth waves is *quite rapid*, it varies through a very wide range.

Duration of Earthquakes. — Earthquakes may be momentary, or they may consist of several successive shocks, and these may be repeated during long periods. After the earthquake which in 1766 destroyed a large portion of the city of Cumana in Venezuela, shocks were felt nearly every hour for 14 months; and

in Calabria, southern Italy, beginning with the earthquake of February, 1783, they were felt for nearly four years.

In Saint Thomas, also, after the earthquake of 1867, and at

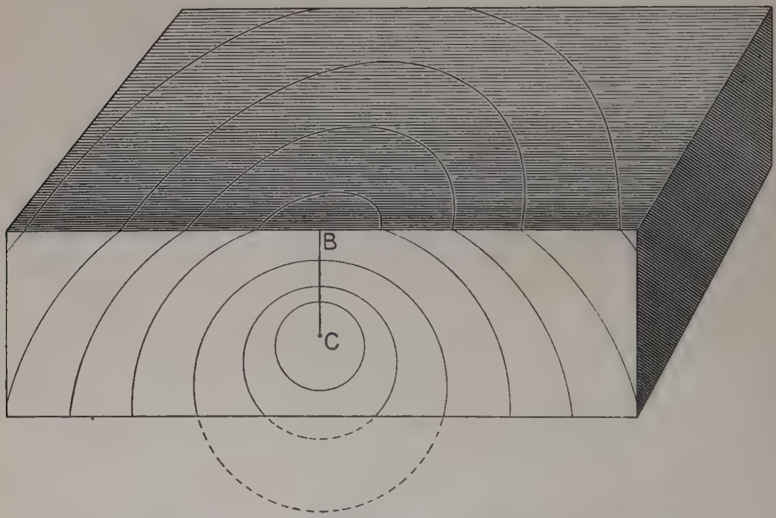


DIAGRAM ILLUSTRATING THE ELLIPSOIDAL SHAPE OF EARTH WAVES

C, the centrum in one focus of the ellipsoid; *B*, the epicentrum. In the passage of the waves from the centrum to the epicentrum they would constantly encounter less coherent matter and their velocity would be diminished. This is shown by decreasing the distance between the waves. In the opposite direction, for reasons stated in the text, their velocity would be accelerated. This is shown by increasing the distance between the waves. Likewise in other directions the passage of the waves would be affected more or less according to the depth below the surface, thus producing the ellipsoidal shape.

Charleston after that of 1886, minor shocks were felt for many weeks.

Area of Disturbance. — The area through which the disturbance extends may be very large. The shock of the earthquake of Lisbon, in 1755, was definitely felt as far as Finland in one direction, and as far as Madeira in another.

The disturbance affected the sea to a much greater distance The water rose among the West Indies so that Antigua,

Martinique, Guadeloupe, and Barbados were partly overflowed. The area disturbed was four times as large as Europe.

The Charleston earthquake was the most severe ever experienced in the eastern part of the United States. Shocks were felt from New England to Florida and from the Atlantic coast to the middle of the Mississippi Valley. It has been estimated

WRECK OF A BUSINESS BLOCK, CALIFORNIA EARTHQUAKE OF 1906

that the area of disturbance embraced fully one fourth of the entire country, shocks having been felt in no less than 28 states.

Great Sea Waves are caused by earthquakes which have their center beneath the ocean bed.

The water at first recedes from the beach, and exposes the sea bottom even beyond the usual limits of low water. Then the sea wave comes in with a steep front or wall which may be 50 or 60 feet high. It drives back the receding water, and

deluges the shore, sometimes demolishing whole towns. It often passes inland to the distance of several miles. The inhabitants, when possible, rush to the hills, and remain there until the wave subsides. In many instances the loss of life has been appalling.

The great wave of the Lisbon earthquake was 60 feet high at Cadiz. It rose and fell 18 times at Tangier, Africa.

In 1854, when Simoda, in Japan, was destroyed by an earthquake, the sea wave completely overwhelmed the place. The receding wave actually crossed the Pacific, and made the water rise on the coast of California.

Again, in June, 1896, during an earthquake having its center beneath the Pacific off the northeastern coast of Hondo, Japan, the shore of that island for the distance of 70 miles was washed by a great sea wave. Many villages and towns were destroyed and upward of 30,000 people perished. The magnitude of the sea disturbance is shown by the fact that at Honolulu, 3591 miles away, waves attained a height of eight feet above high water. As in the preceding case, the disturbance was registered by proper instruments on the coast of California.

The earthquake at Arica, Peru, in August, 1868, was likewise remarkable on account of the size of the accompanying sea waves. Owing to the fact that the waves travel faster through the land than through the water, to the ruin wrought by earth shocks was added the destruction caused by the inundation of the sea.

After the passage of the first earth waves the water receded from the shore, then it rose to the height of 30 feet and overflowed the town. Again the water receded, and again it rose in a great wave. Then came terrific shocks followed by the advance inland of a perpendicular wall of water, from 42 to 45 feet in height, capped with foam. It rushed over the land, carrying with it several ships, among them two naval vessels, which were left stranded far from the shore.

Sea waves are often perceptible throughout an entire ocean basin. They travel across the Pacific at the rate of about 350 miles an hour.

If the center of the earthquake is beneath the land, so near the coast as to disturb the sea, the waves produced are thrown out from the shore and are harmless. This explains why, although the Charleston earthquake was felt at sea as far as the Bermudas, no wave damage was done in the harbor of Charleston.

Destructive Effects. — Earthquakes are perhaps the most impressive manifestations of power in the material world. The destruction of life and property occasioned by them is often

enormous. On the 1st of November, 1755, Lisbon was shaken by the "great earthquake," and in six minutes its palaces were in ruins and 60,000 of its inhabitants were dead.

In March, 1812, Caracas, in Venezuela, was destroyed, with 10,000 of its inhabitants.

Upheavals and Depressions. — Geological changes of great importance often accompany earthquakes.

In the year 1819 an earthquake occurred in the region adjacent to the mouth of the Indus. It completely destroyed the town of Bhooj, and was felt within a radius of hundreds of miles. A tract to which the natives gave the name of "Allah Bund," or "Mound of God," was raised where, before, there had been a level plain. The "Bund" was 50 miles long, 16 miles wide, and about 10 feet high. At the same time the fort and village of Sindree, with the neighboring region, subsided; the sea flowed into the sunk area, and an inland sea was formed covering 2000 square miles.

During the earthquake at New Madrid, on the Mississippi, in 1811–1812, which covered a period of several months, an area, 75 or 80 by 30 miles in size, lying west of the town and since known as the "sunk country," was permanently submerged.

Distribution of Earthquakes. — No part of the earth is entirely free from earthquakes. In certain parts of Japan tremors are felt every day. Vessels not unfrequently report earthquake shocks at sea.

In the Old World they are most frequent in a region which embraces the northern shores of the Mediterranean Sea, and extends eastward into the central portions of Asia.

In the New World earthquakes are far more common than in the Old. Both the eastern and western mountain regions of North America are subject to them, but the region of greatest frequency is in South America. It comprises Ecuador, Peru, and Chile.

In many places within this region the houses are built of reeds and bamboo, lashed by thongs of bull's hide, and secured in their places with cords instead of nails, that they may yield to the shocks without being shaken to pieces.

Causes of Earthquakes. — Earthquakes have been attributed to various causes, such as displacements of the earth's crust, slumping, volcanic action, and the collapse of caverns.

(1) Geologists are of the opinion that in most instances an earthquake is due to the formation of a fissure in the crust, and that, in the process of readjustment following, one wall slips or

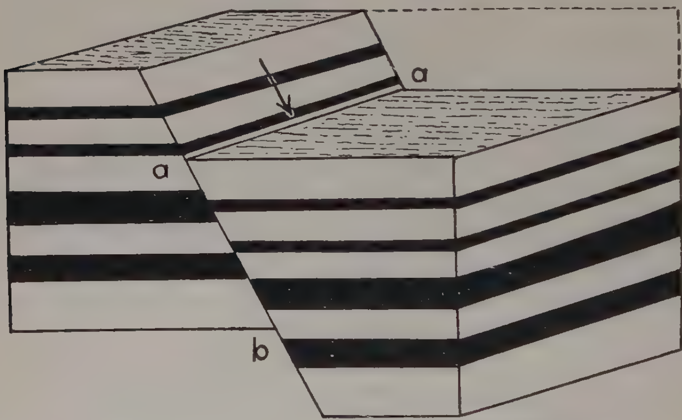


DIAGRAM ILLUSTRATING FAULTING OF THE EARTH'S CRUST
aab, fault fissure.

slides over the other with sufficient violence to produce a series of jolts or jars. These, transmitted through the adjoining rocks, constitute an earthquake. The displacement is known as a fault; earthquakes, therefore, may result from the *faulting of the crust.*

Faulted rocks are illustrated in the accompanying figure. By the formation of the fissure *aab* and the resulting displacement, the strata on the right, or downthrow side, have dropped to a lower level.

The great California earthquake of April 18, 1906, the severest known on the Pacific coast of the United States, was undoubtedly caused by the shifting and readjustment of the rocks along an old line of weakness or faulting extending from Bolinas Bay, north of the Golden Gate, over the peninsula of San Francisco to Salinas and perhaps farther south.

While the damage resulting from earth movements was very great both in San Francisco and the neighboring towns, to the calamity in San Francisco was added the tremendous loss of property by fire, which, following the collapse of buildings, swept over the entire business portion of the city.

But if earthquakes are produced by faulting, how is that phenomenon to be explained? It is now believed to be one of the results of the cooling and contraction of the interior of the earth. As the inner rocks cool and contract, they shrink away

FISSURE OF DISPLACEMENT, JAPAN EARTHQUAKE OF 1891

from the outer layers, some portions of which are left without support. Under the pressure of gravity they may now bend or they may break. Having broken, they may slide and grind on the lower wall of the fissure. The effect upon the senses may be faintly illustrated by the jarring and noise produced by a heavy body of snow when it slides from the roof of a large church.

By reference to page 86 it will be seen that the above cause furnishes the best explanation yet offered not only for the formation of faults and fissures, but also for the formation of the great mountain systems of the earth, whether of the folded or block type. If this view be correct, then, when mountain making is going on, earthquakes should be of common occurrence. We have

reason to believe that such was the case in the past, as it undoubtedly is in the present.

(2) There are earthquakes which seem to arise from volcanic action, especially that of the explosive type, but tremors of this kind affect a much smaller area than the preceding. As to their cause, it has been suggested that the sudden formation and explosion of steam within a cavity of the earth or its rapid condensation accompanied by a collapse might account for the phenomena, or, in other cases, the penetration of the rocks by molten lava.

Displacement of Railroad Track by Earthquake Fault or Rift. Two Views of the Track of the North Shore Railroad at Tomales, Marin County, California, after the Earthquake of 1906

Earthquakes are of common occurrence in the vicinity of the Mediterranean volcanoes, Vesuvius, Etna, and Stromboli.

An earthquake of unusual severity occurred on the slope of Mauna Loa, a Hawaiian volcano, in the spring of 1868. For six days shock followed shock with increasing violence. "The ground rolled in great waves, rapidly swaying in every conceivable direction, including the vertical." The crests of the earth waves cracked open; finally a sheet of molten lava was projected violently skyward.

(3) In some instances earthquakes of a local character have been attributed to the collapse of caverns. In limestone regions especially, through the dissolving action of subterranean water,

FAULT LINE AT OLEMA, MARIN COUNTY, CALIFORNIA. TYPICAL APPEARANCE IN HARD GROUND. EARTHQUAKE OF 1906

large caves are formed. As they are enlarged their roofs are weakened and in places may finally fall. The jar thus produced may be sufficient to account for a small earthquake.

The collapse of Mount Cernans in 1840 has been cited as an example of the probable action of underground water. The Jura Mountains are especially noted for their large springs. In this particular instance many years before a large spring had disappeared which thereafter, by dissolving the underlying rock, may have made possible the fall of the mountain. Earthquakes from such a cause are not common.

PART II.—THE LAND

VIII. THE LAND MASSES

Relation of Land, Water, and Air.—In the preceding pages we have regarded the earth as a whole. In those which are to follow we shall consider somewhat in detail those parts of the earth which are accessible to man—the solid portion or *lithosphere*, the watery portion or *hydrosphere*, and the aerial portion or *atmosphere;* we shall also consider the phenomena which belong to each and the forms of life which they support.

Although easily recognized and apparently distinct, the lithosphere, hydrosphere, and atmosphere interpenetrate one another in a most remarkable manner, and this interpenetration has a most important bearing upon *life*. Were it not for air in the water, fish would perish; were it not for water in the ground, most plants would die and animals starve; were it not for water in the atmosphere, rainfall would cease and desolation reign. Further illustrations are unnecessary to show that the land, the water, and the air are to be regarded as parts of a great mechanism which contributes in a variety of ways to the maintenance of plant and animal life.

Distribution of Land.—Of nearly 197,000,000 square miles which embrace the surface of the earth, about 142,000,000 are covered by water, and 55,000,000 by land. In other words, there is over two and one half times as much water as land.

The land is found in masses of irregular shape and size, which are separated by intervening portions of water. The three largest continuous land masses are called *continents*. The smaller masses of land are called *islands*.

Most of the land is in the northern half of the globe. It

surrounds the North Pole in an almost continuous ring, and from the polar regions it extends in long irregular masses toward the south. We may consider the great land masses as forming three pairs of *grand divisions*. The pair comprising North America and South America affords the most perfect example of this arrangement; that consisting of Europe and Africa is less well defined; while that is most irregular which comprises Asia and Australia.

In regard to *shape* the grand divisions follow a general law. They spread out broadly toward the north, while toward the south they taper to points, or throw out peninsulas. Thus, in general, they approach the form of a triangle. This is strikingly illustrated in the case of Africa and the two Americas. Europe and Asia combined form a vast triangle. Australia is the only marked exception to the rule.

Almost all the large peninsulas are southern projections from the grand divisions.

Northern and Southern Hemispheres. — The globe is divided by the equator into a Northern and Southern Hemisphere. North America, Europe, and Asia, two thirds of Africa, and a portion of South America are contained in the Northern; Australia, part of Africa, and the greater part of South America, in the Southern. There is three times as much land in the Northern as in the Southern Hemisphere.

The Northern Hemisphere is the seat of knowledge, civilization, and power. It is the commercial hemisphere.

The Southern Hemisphere has never been the seat of power. The Peruvians and the Javanese were the only nations which attained a high degree of civilization there. Only about one fifteenth of the population of the globe have their home within this hemisphere.

Land and Water Hemispheres. — The earth may be divided into two hemispheres, one of which contains nearly all the land, and the other nearly all the water. These hemispheres are known as the Land Hemisphere and the Water Hemisphere. London is nearly at the center of the Land Hemi-

sphere; New Zealand nearly at that of the Water Hemisphere. Australia presents the largest extent of land in the Water Hemisphere.

Coast Line of the Grand Divisions. — Everywhere the sea more or less deeply indents the land. These indentations form navigable seas or sounds, harbors or roadsteads. The length and

THE LAND HEMISPHERE

indentation of the coast line, therefore, are indications of the commercial capabilities of a grand division.

Comparing the several grand divisions, we find that the southern have far more regular outlines than the northern. Their indentations are comparatively limited, and their coast line short. The contrast is most marked between Europe and Africa.

Europe has six times more coast line in proportion to its area than Africa. The effect of this has been very important in the history of the two grand divisions. By the multitudinous seas, bays, and gulfs of Europe intercommunication of one part of the grand division with another, and with other portions of the world, has been facilitated, and thus its several countries have been

The Water Hemisphere

rendered accessible to commerce and civilization. Europe has enjoyed among the grand divisions the leadership in commerce.

Africa, on the other hand, with its comparatively unbroken coast line and scanty harbors, has been rendered by nature far less open to extensive intercourse with the outside world.

North America, though in a less degree than Europe, is preëminent for the indentation of its sea coast. This con-

tributes to render it the companion of Europe in commerce and civilization.

Coast Lines not Permanent. — In past ages of the earth much that is now land was accumulated beneath the sea in the form of silt, sand, and limy deposits. From time to time these deposits were elevated above the water, forming new land. Thus coast lines were changed and the shape of the land masses altered. But this was not all. There were movements of depression as well as elevation. By the sinking of the land rivers were drowned and estuaries formed, and by the subsidence of coastal mountains, islands were left as offshore monuments of a retreating coast. These are some of the results arising from *diastrophic* or great earth movements. Even during the present time in many places the land has given way before the incessant beating of the waves, while in other places the shore has been extended by the formation of sand reefs and mud flats. So it must have been in the past. The coast lines, therefore, are not permanent and the shape of the continents has undergone many alterations. There has been, however, an upbuilding or evolution of the land from the primitive nuclei to the more highly developed areas which now furnish an abiding place for man. Yet, notwithstanding these changes, broadly speaking, both the land masses and the oceanic basins exhibit a high degree of permanency.

IX. RELIEF OF THE LAND

General Statement. — The *relief* of the land is shown by its "physical features," or the irregularities of its surface, such as plains, hills, plateaus, mountains, and valleys. Although differing greatly in form, they represent, in the main, the combined results of two opposing forces: earth movements and erosion.

By *earth movements* reference is made not only to the great upheavals by which the continents were elevated, but also to the yielding of the earth's crust, through folding and faulting, in the formation of mountains. By *erosion* is meant the wasting or degrading of the land, chiefly by the action of water, whether in the liquid or the solid state. By this action all elevations are more or less modified, and in the past plateaus and even mountains have been reduced to the condition of low plains.

Relief, therefore, cannot be regarded as permanent. The forces concerned may act with great slowness; but *time is long*, and although the changes wrought are apparently insignificant, their ultimate result may be to change completely the physical aspect of the land.

Mean Height of the Land. — The average elevation of the continents is not great. It has been estimated that if all the mountains were leveled, and all the valleys filled up, the land of the globe, taken as a whole, would not be raised, on an average, much over 2400 feet above the sea.

Although the mountains are so massive in size, and reach so far toward the heavens that their highest peaks can with the greatest difficulty be scaled, yet, when compared with the size of the earth, their huge proportions dwindle into insignificance.

A mountain five miles high, which is higher than any but the loftiest peaks of the Himalaya or Karakoram, rises above the sea level but $\frac{1}{800}$ part of the

earth's radius. Hence upon a globe 16 inches in diameter, it would be represented by an elevation of only $\frac{1}{100}$ of an inch, about the thickness of three leaves of this book.

On a globe 16 feet in diameter, the highest mountains would rise above the surface less than one eighth of an inch.

Forms of Relief. — According to their relief, the various forms of land are classified as lowlands or highlands.

Lowlands are usually elevated less than 1000 feet above the sea. They are commonly called plains.

Highlands have an elevation of 1000 feet or more above the sea. They are called plateaus or table-lands and mountains. Hills are inferior elevations. They may rise from plains or from plateaus; they may fringe a table-land from which they have been separated by erosion; or they may be piled one above another at the base of mountains. In the condition last mentioned they are termed *foothills*.

Between the various forms of relief sharp distinctions cannot always be drawn. Plains, for example, may gradually pass into plateaus, and hills may so closely resemble mountains as to be with difficulty separated from them.

Plains are those portions of the earth's surface which have only a moderate elevation above the sea. They may be level, rolling, or diversified with hills. When covered with grass and generally destitute of trees, they are called *prairies* in our country, *pampas* or *llanos* in South America, and *steppes* in Asia. The densely wooded plains of the Amazon are called *silvas*. About one half of the continental surfaces consists of plains.

For convenience plains may be grouped as follows: coastal plains, river and lake plains, and interior plains. It must be understood, however, that these groups are not always distinct, for one form may imperceptibly blend with another, as is conspicuously shown in the case of the Gulf coastal plain and the flood plain of the Mississippi River in several of the Southern states.

Coastal Plains, as their name implies, are those bordering coasts. They have been formed beneath the sea and later elevated into land. Of this there can be no doubt. The loosely

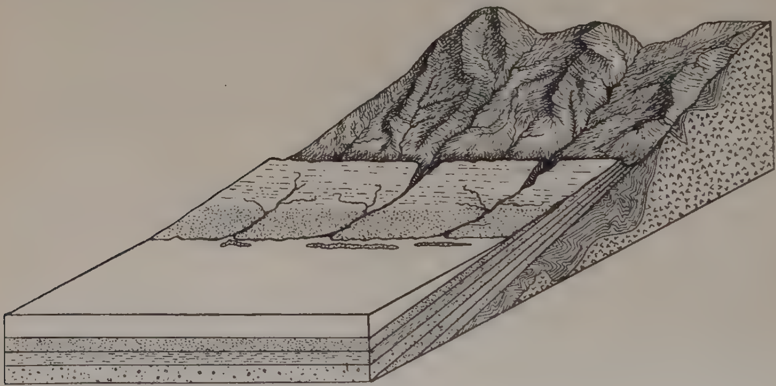
compacted strata of sand and gravel, the beds of silt and clay, the presence of sea shells and the hard parts of other marine animals furnish indisputable evidence. Such plains, lying between the highlands and the shore, are in some instances quite *broad*, as along the Atlantic coast of the United States from New Jersey southward; in other instances they are *narrow*,

A NARROW COASTAL PLAIN

sometimes quite narrow, as shown by the low-lying strips fringing, in many places, the Pacific coast of both North and South America.

The beds or strata underlying a coastal plain incline or dip seaward at a low angle. They are also of varying degrees of hardness. As soon as the newly made plain emerges from the sea a stripping of its surface begins. The chief agents concerned in this are rain, running water, and ice, and the process as a whole is termed *denudation*. Streams from the higher land now pass down over the plain, excavating shallow channels. As the plain rises higher, the stream ways are deepened and tributary streams may originate upon its surface. The softer the rocks, the more rapid the denudation becomes. If in

time it should happen that where the softer strata outcrop the plain is trenched and where the hard strata outcrop there is left a belt of upland, presenting a scarp to the interior and a



A Belted Coastal Plain

The strata are inclined (dip) seaward. At the base of the upland the plain is trenched. Here the weaker strata have yielded to erosion, while the harder strata above form an inward-facing scarp.

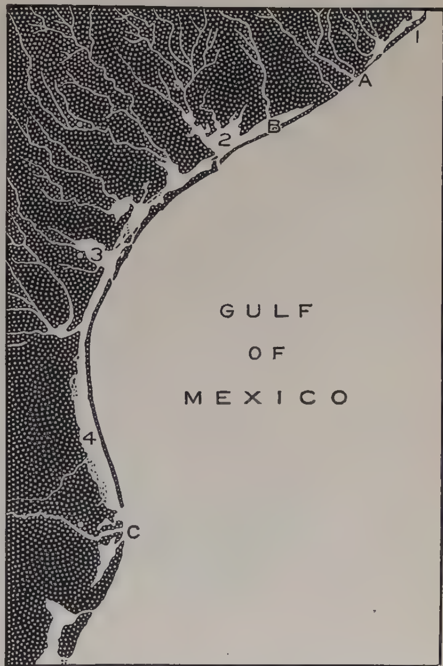
seaward slope to the exterior, on account of its belted relief such a plain would be termed a *belted plain*.

The conditions above described appear in southern New Jersey. Here the Delaware River in its lower course flows in the trenched portion of the coastal plain. To the southeast the land becomes hilly and passes into an upland belt which on its seaward side slopes gradually to the lowland skirting the shore.

River and Lake Plains are often termed *alluvial plains*. They have been formed from materials washed down from hills and mountains. In the lower course of a river, where the amount of sediment received is greater than the current can urge onward, the inequalities of the river bed are buried beneath alluvial deposits which form a bottom land subject to overflow in times of flood. Such an area is known as a *flood plain*. An extension of a flood plain into a lake or sea may take place, and if the stream is impeded by the accumulated matter, it may discharge

through several mouths, forming a *delta*. By the growth of a delta a *delta plain* is formed.

The flood plain of the Mississippi River below the mouth of the Ohio, exclusive of the delta, has an estimated area of 16,000 square miles. Its width, between the high banks or bluffs, varies from 20 to 80 miles. The area of the Mississippi delta is approximately 12,300 square miles. The combined delta of the Ganges and Brahmaputra rivers is of very great size, some estimates reaching 50,000 to 60,000 square miles. The typical delta, shaped like the Greek letter of that name, is that of the Nile. Its area is about 9000 square miles. These illustrations serve to show the magnitude of river deposits. Even where true deltas are not formed the extension of the coastal plain seaward by river action is seen in the formation of *delta shore lines*.



DELTA SHORE LINES OF THE GULF COAST

By the deposition of waste, stripped from the higher lands by the Brazos, *A*, the Colorado, *B*, and the Rio Grande, *C*, the coastal plain has been extended gulfward, giving rise to "delta shore lines." 1, Galveston; 2, Matagorda Bay; 3, Corpus Christi Bay; 4, Laguna Madre.

Attention is also called to the long, sandy, reef-like islands inclosing the bays and lagoons.

The Nile Valley and that of the Menam in Siam are annually overflowed, and covered, when the flood subsides, with a fine sedimentary deposit. This consists of rich fertilizing materials brought down from distant mountain slopes. It imparts perennial fertility. It has clothed the land of Egypt with verdure since the days of the Pharaohs, thousands of years ago. It secures the great rice crop of Siam.

Streams emptying into lakes tend to fill them with deposits of gravel, sand, and mud, while in smaller bodies of water the

growth of vegetation is considerable. If above the sea level, the outlets of these lakes are gradually lowered by erosion and in the course of time they are drained. In this manner many lake plains have been formed. In some instances the drainage of lakes may not be complete, or the exposure of the lake de-

THE NILE AT FLOOD

posits may be due to the warping of the earth's crust. In such cases the level areas exposed along the shore are also designated as lake plains. In some parts of the world, too, lake plains have resulted from desiccation, or the drying up of the lake waters, due to climatic changes. Where arid conditions still prevail, these old lake bottoms now form desert plains.

Interior or Inland Plains are those lying within the continents. More or less inclosed by mountains and drained by large rivers, they partake of the general character of valleys, but are on a grander scale. Their origin is not due to river action, but rather to the great forces of upheaval whereby continents have been

elevated and mountains formed. Broadly speaking, the surface of these plains is rolling or undulating, but many areas of considerable extent are quite level. The great central plain of North America, lying in the basins of the Mississippi and Mackenzie rivers, and the combined plains of the Orinoco, Amazon, and Plata rivers in South America, afford excellent examples of this class.

That portion of the interior plain of the United States lying at the base of the Rocky Mountains is known as the "Great Plains." It is treeless, owing to the arid conditions prevailing there, and on account of its unusual altitude is often classed as a plateau. While its appearance is that of an extended prairie region, it should not be confounded with the true prairies lying at a lower altitude and nearer the Mississippi River. They are fertile areas of treeless land susceptible of high cultivation.

Base Level and Peneplains. — When a stream has cut its channel down to the level of the body of water into which it empties, it can excavate its bed no deeper. It has reached its lowest point, or *base level*. Such a stream, if it flows across a plain, will now begin to meander, cutting away its banks laterally. As this proceeds, the inequalities of the plain will eventually disappear until the plain itself is base-leveled.

To indicate a stage preceding that just described, in which the divides between the streams may still be recognized as low, rounded, but inconspicuous hills and swells, the term *peneplain* (almost a plain) is employed.

It has frequently happened in geologic time that plains, plateaus, and even mountains, by the incessant action of the erosive agents, have been reduced to the peneplain or base-level state.

Plains the Centers of Civilization. — Owing to their fertility and ease of cultivation, plains have been, throughout the history of man, centers of population, civilization, and power. The imperial glory of Nineveh and Babylon, the culture of ancient Egypt, the enduring prosperity of China, and the unrivaled wealth of India, all owe their origin to the rich soil brought by the rivers from the hills.

Plateaus or Table-lands are broad, elevated uplands. As stated by Gilbert, "they may be indefinitely bounded; they may be limited on all sides by cliffs overlooking adjacent areas; or descending cliffs may limit on one side and ascending cliffs or slopes on the other." The names employed suggest flatness. Some plateaus, as the Llano Estacado of Texas, are as level as the prairies. Generally, however, plateaus present a highly diversified surface, hills and even great mountains rising from them.

The plateau of Tibet consists of plains and wide basins, some of which contain large lakes, engirdled by ranges of gigantic snow-clad mountains.

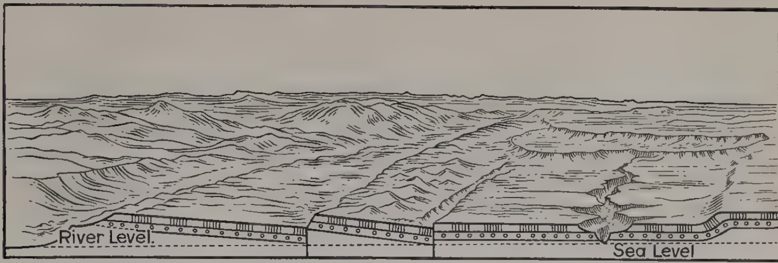
The aspect presented also by the great plateau lying between the Rocky Mountains and the Sierra Nevada in our own country, is that of a vast uplifted mass from which the mountains rise; while the Bolivian plateau, in South America, with the towering peaks of the Andes embosoming its upland lake, singularly resembles the plateau of Tibet.

In elevation plateaus vary greatly. Low plateaus, like the desert of Sahara, are from 1000 to 3000 feet in height. The loftiest in the world are the plateau of Tibet, 10,000 to 15,000 feet high, and the Bolivian plateau, averaging about 12,000 feet.

Kinds of Plateaus. — According to their origin plateaus may be divided into two groups: *diastrophic plateaus*, those resulting from the great forces of upheaval; and *vulcanic plateaus*, those resulting from the outpourings of molten rock or lava.

Diastrophic plateaus, like the plains bordering the continents, have been elevated above the level of the sea. In many instances they are composed of stratified rock, sandstones, limestones, and shales. Oftentimes the strata or layers have suffered little, if any, displacement, the whole area having been lifted bodily. In some regions, however, the rocks have been broken, by faulting, into great blocks, now arranged like a series of steps, each of which gives rise to a plateau of a different altitude. This structure is particularly characteristic of the

plateaus trenched by the Grand Canyon of the Colorado River in Arizona, which have been termed *broken plateaus.*



BROKEN PLATEAUS

Part of a section from west to east across the plateaus north of the Grand Canyon of the Colorado. From Powell.

Vulcanic plateaus have been formed by the cooling of great lava floods. In the best-known examples the molten rock seems to have welled up through fissures in the crust now completely concealed beneath the successive outpourings.

In the northwestern part of the United States there is a vast area, not less than 150,000 square miles in extent, embracing portions of northern California, Nevada, Idaho, Oregon, and Washington, covered with these surface flows or sheets. Where cut by the Columbia River the aggregate thickness of the sheets composing this plateau is found to exceed 3000 feet.

Erosion of Plateaus. — By the action of rain and flowing water plateaus are gradually worn away, or *eroded.*

Streams originating upon or crossing a recently elevated table-land deepen their channels until canyonlike valleys are formed. In this manner a plateau is *dissected.*

As the stream wear continues, tributaries are extended, canyon walls undermined, and valleys broadened. In the meantime the intervening land, or ridges, assume somewhat of a mountainous aspect, the rather uniform sky line serving in a general way to indicate the surface of the former plateau. As stream dissection and erosion continue, the ridges become lower and less conspicuous until they finally disappear, save here and there a

flat-topped hill, or *mesa*, capped with a layer of hard, resisting rock. The plateau has now reached the *worn-down* stage.

Plateaus cut by canyon valleys may be classed as *young;* those well dissected by stream ways, with intervening hills or "mountains," as *mature;* and the worn-down plateau, as *old.*

THE BAD LANDS OF SOUTH DAKOTA

Illustrating the effects of erosion upon soft rocks in an arid region. Unprotected by vegetation, the valley walls are readily sculptured by water action notwithstanding the scanty rainfall.

Plateaus Unproductive. — The plateau regions of the world are for the most part unproductive. Many of them are absolute deserts. Hence few plateaus have ever become centers of population and power. It is interesting, however, to observe that the table-lands of Mexico, Peru, and Tibet have each been the seat of a civilization peculiarly its own.

The desert plateaus have undoubtedly their part to perform in the economy of nature. They are not wastes in the sense of being wasted or useless areas. Their effect upon the rainfall and its distribution is most important. It will be more fully considered when we treat of the moisture of the air.

THE MATTERHORN, OR MONT CERVIN

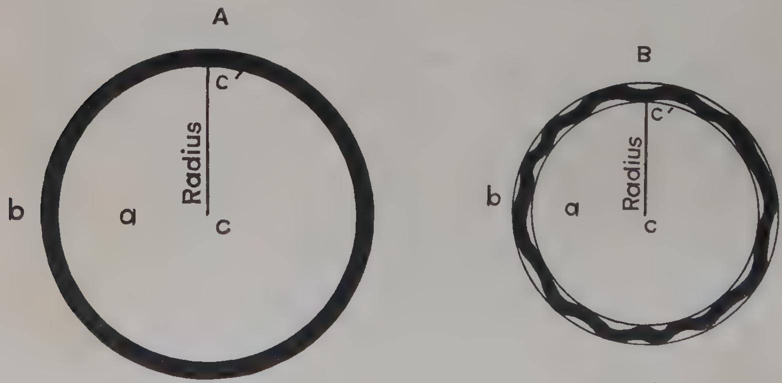
This celebrated peak has an altitude of 14,705 feet. From stereograph. Used by permission.

Mountains. — The higher and more conspicuous elevations of the earth's crust are termed *mountains*. Although they sometimes stand singly, as Etna or Vesuvius, more often they are

joined together in the form of a connected series called a *range* or *chain*. Mountain chains seldom occur solitary. Usually two or more are parallel, or nearly so, forming a mountain *system*. Of this the Andes, the Alps, and the Appalachians afford striking examples.

Descriptive Terms. — Isolated summits are called *peaks*. The top of a ridge from which there is a descent in opposite directions is known as a *crest*. The slopes of a ridge or peak constitute its *flanks*. A ridge or group of ridges presenting a serrated or notched sky line is called a *sierra*. Sharp-pointed peaks are spoken of as *horns*, a term especially used in Alpine regions.

The Formation of Mountains. — Mountains have been formed in at least four ways: by folding or crumpling, by faulting, by vulcanism, and by erosion.



A Representation of the Effects of Contraction upon an Outer, Yielding Spherical Covering

In *A* the interior of the sphere, *a*, is shown before contraction. The coat *b* fits closely upon it. In *B* the interior of the sphere, *a*, is shown after contraction. The non-shrinking coat, *b*, in order to fit upon it is now thrown into folds. The amount of contraction is shown by a comparison of the radius in *A* with that in *B*.

(1) The folding process is thought to be a result of contraction. The crust of the earth is regarded as a spherical shell or coat, now practically cool, surrounding a heated, but cooling

and therefore shrinking, interior. Under the influence of gravity the crust is drawn downward, that is, toward the center of the earth, and thus a larger spherical surface is made to fit closely upon a smaller. This can be brought about only by the folding, crushing, and breaking of the crust.

Although serious objections have been brought against this

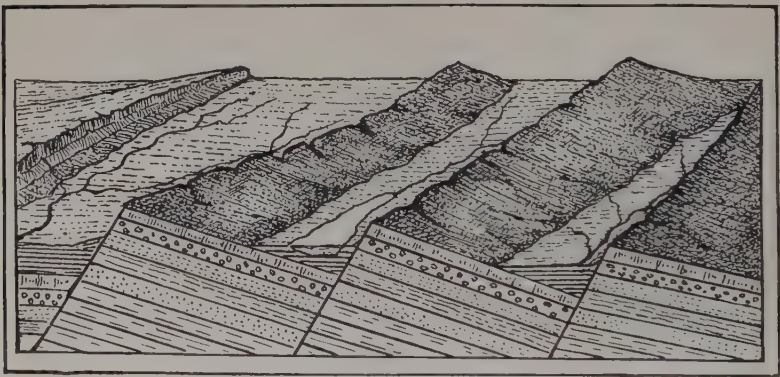
AN UPWARD FOLD OF THE EARTH'S CRUST (ANTICLINE), NEAR HANCOCK, MARYLAND

theory, the fact remains that many of the most prominent mountain systems are composed of folded, crushed, and disturbed strata, as is well exemplified in the Appalachian and Jura Mountains.

(2) In the region of the Great Basin, between the Sierra Nevada and the Rocky Mountains, there is found a type of mountain structure due primarily to faulting: long, narrow ridges with a cliff, or scarp, on one side and a gentle slope on the other. Here it would seem that a great plain had been upheaved in the form of a mighty dome which, owing to tension, or stretching, was traversed by numerous cracks or fissures.

Finally, by the collapse of the dome, the long, narrow, parallel blocks were displaced or faulted and each became a mountain ridge.

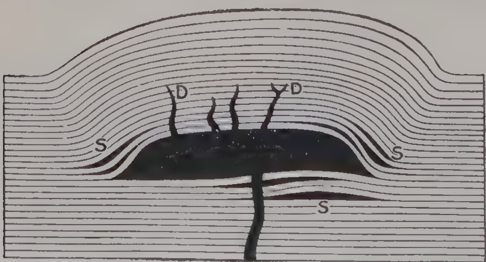
(3) The formation of ordinary vulcanic mountains has already



DIAGRAMMATIC ILLUSTRATION OF BLOCK MOUNTAINS

The tilted blocks are carved into hills and mountains and cut by narrow, canyon-like gorges, while the valleys between them are filled with wash, sand and gravel, brought down from the adjacent heights. The streams in such a region either are lost in the sands or flow into lakes, permanent or temporary.

been illustrated in the description of volcanoes, the cones of which are built up by the ejectment of cinders and ash, the outpouring of lava, or by both of these processes.



IDEAL SECTION OF A LACCOLITE. After Gilbert. *S*, sheets; *D*, dikes.

There is, however, a type of vulcanic mountain of quite a different structure. Through a fissure, or conduit, in the earth's crust, not reaching the surface, molten matter from below has been forced, which, spreading out, lifts the overlying strata bodily upward in the form of a dome. Later this elevation is eroded or worn away, exposing

in many places the interior igneous filling, known as a *laccolite.* Such mountains are said to have a laccolitic structure.

(4) As already stated, dissected plateaus may give rise to a rugged country. Here the mountains may be flat-topped, with summit scarps or cliffs, and sloping flanks covered with rock waste (talus), or they may be rounded off and subdued as in

THE BORDER OF THE EDWARDS PLATEAU ON THE COLORADO RIVER, WEST OF AUSTIN, TEXAS

the region of the Allegheny plateau bordering the Appalachian Mountains on the west.

Valleys are depressions through which usually water courses run. Every mountain range is intersected by valleys, and every mountain system has valleys separating its parallel ranges. The valleys intersecting ranges are called *transverse.* Those lying between parallel ranges, and having therefore the same general direction, are called *longitudinal.*

In regions of folded mountains the formation of valleys is largely due to the upheavals and depressions which have disturbed the surface of the earth. The formation of valleys is

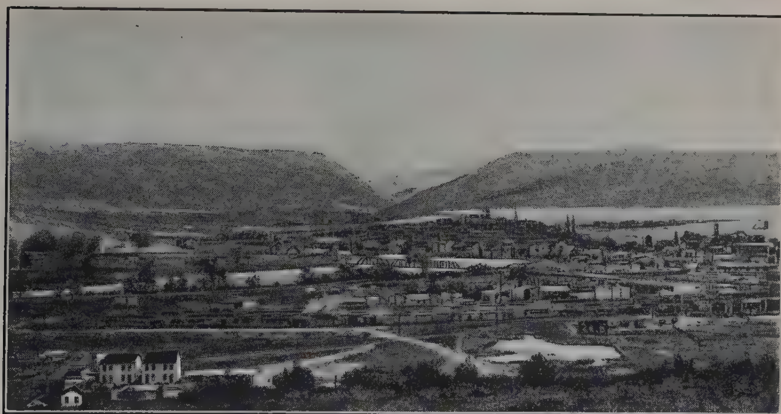
Grand Canyon of the Colorado

really a part of the process by which mountains are made. The action of running water has, of course, widened and deepened them.

Valleys traversing plains and plateaus have been formed by

the erosive action of water. Of such valleys the most extraordinary in the world are the canyons of our Western rivers.

That of the Colorado is a gorge shut in by almost perpendicular walls of rock. It is from 3000 to 6000 feet in depth and 300 miles long. Canyons are among the most impressive evidences of the age of our earth. Thousands of years would be a brief period for the work of wearing away solid rock by running water to the depth of more than a mile as in the case of the Grand Canyon of the Colorado.



A WATER GAP

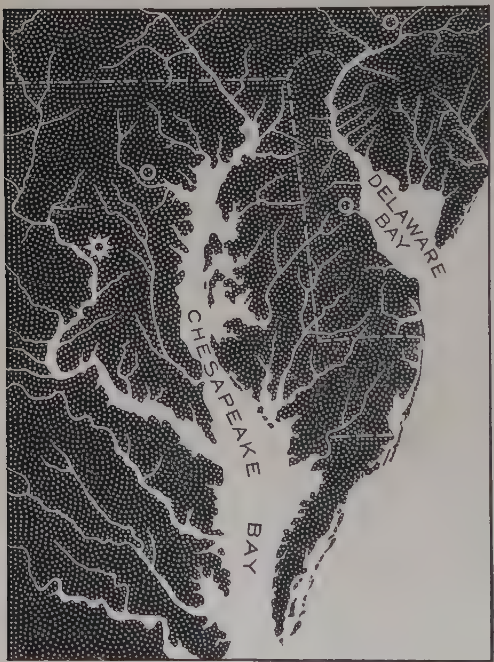
The Narrows of Wills Mountain, Maryland. Cumberland in the foreground. From Geological Survey of Maryland.

The heading together of transverse valleys renders it possible to cross lofty mountain ranges. Human ingenuity and industry have improved these natural courses of travel, or *passes*, as they are called, and some of them have been made marvels of engineering skill. The Simplon, Saint Bernard, and Saint Gothard passes, crossing the Alps, are among the most noted. The Alpine railroad tunnels have, to a large extent, taken the place of the passes. In the eastern portion of the United States the narrow transverse valleys, through which streams flow, are termed *water gaps*.

General Elevation of the Land. — Among the best evidences of continental elevation are those furnished by raised sea

beaches, water-worn caves, and terraces now found far above the seat of wave action, and by the occurrence, at various elevations, of coral reefs and the shells of marine animals still adhering to the rocks upon which they grew.

In some parts of Great Britain (geologically a part of the Eurasian continent) raised sea beaches, five or six in number, are found at different levels up to 100 feet, and on the Norwegian coast there are numerous ice-cut terraces, which represent successive old shore lines. Modern coral rock has been reported by Alexander Agassiz as occurring in Peru at the height of 3000 feet above the sea level, and raised coral reefs are found in several places fringing the Red Sea.



A DROWNED RIVER — CHESAPEAKE BAY

The above are a few of the many examples that could be cited illustrating the elevation of the land masses with reference to the sea level.

General Subsidence of the Land. — In many parts of the world there is evidence of the sinking or subsidence of the land. This is shown in drowned valleys, estuaries, and fiords, and in the submerging of forests as well as of the works of man.

The sinking of the west coast of Greenland is a familiar example. Here the inhabitants fasten their boats to poles or piles driven off the shore. After long intervals, by the subsi-

dence of the bottom, the poles disappear beneath the surface of the water and must be reset.

The stumps of cypress trees show submerged forest land on the coast of South Carolina and Georgia; and near the head of the Bay of Fundy, in Cumberland County, Nova Scotia, the stumps of pine and beech trees, still embedded in the soil on which they grew, are covered to the depth of 25 to 35 feet at high water.

The coast of New Jersey also may be cited as a region of

AT THE HEAD OF CHESAPEAKE BAY

Elk and Bohemia rivers from Elk Neck. From Geological Survey of Maryland.

subsidence, the estimated rate being about two feet a century; and the estuaries known as the Hudson River and Chesapeake Bay represent the drowning of former river valleys by subsidence. The fiords of the northern coasts furnish examples of the invasion of glaciated valleys by the sea due to crustal sinking.

Causes of Relief. — What force or forces may have caused the general elevation of continents we cannot with certainty tell. On the principle that like effects are due to like causes we should conclude that the elevation of the continents and the formation of folded mountains were produced by similar forces; namely, those resulting from interior contraction and consequent crustal *deformation.* Whatever may be our conclusions on this

point, it is clear that the forces have been at work for ages, at times silently and gently, again with sudden displacements and earthquakes, raising some portions of the earth's surface and depressing others.

Effects of Relief. — The elevations of the earth's surface, although comparatively insignificant, are to be regarded as im-

A NORWEGIAN FIORD

Sörfjord and the village of Odde. From stereograph copyrighted by Underwood and Underwood. Used by permission.

portant regulators of climate. Not many hundred feet added to the relief of a country would suffice to alter its physical aspects entirely, converting vineyards into pasture lands, or pasture lands into regions of perpetual snow. Reverse changes would result from a corresponding diminution in the average elevation.

Again, relief is the great regulator of drainage. If the surface of the earth had been a dead level, without hills, plateaus, and mountains, there would have been no water courses. The whole land would have been one broad marsh incapable of drainage, and unsuited for human occupation.

X. RELIEF FORMS OF NORTH AND SOUTH AMERICA

General Features of Continental Relief. — There are certain features of relief that belong to all the grand divisions of the continents: 1. They are bordered by mountains. 2. They are traversed in the direction of their greatest length by a great mountain system. 3. In each there is usually a subordinate mountain system. 4. In each there is usually a depressed central area.

The line of direction taken by the principal mountain system is termed the superior or main axis of elevation. This line is not, however, in any case centrally placed, as the word *axis* might seem to imply, but far to one side of the grand division, which it thus divides into two unequal slopes. The subordinate mountain system follows the inferior axis of elevation.

North America conforms closely to the general principle of continental relief. It has a superior and an inferior highland, between which there is a rather low, basinlike interior.

The superior highland is known as the Pacific highland, the inferior as the Atlantic highland, and the interior region as the great central plain.

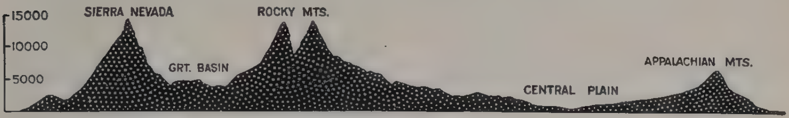
While these three divisions constitute the main features of relief, when considered more in detail it will be found that they include many topographic forms which give rise to *surface expressions* characteristic of the grand division.

The Pacific Highland extends from the Isthmus of Panama to the Arctic Ocean. Its general course is northwest and southeast. Its inner border, facing the interior of the continent, consists of many mountain ranges with lofty peaks, which are collectively known as the Rocky Mountains. Its outer border, facing the Pacific Ocean, also consists of mountain ranges,

THE RELIEF OF NORTH AMERICA

The heavy black lines upon this and the following maps represent, in a general way, the extent and direction of the mountain chains. The elevations and depressions are indicated by the buff and green colors. The buff, according to the depth of its tint, represents elevations of greater or less altitude. The green indicates lowlands.

chiefly the Sierra Nevada and the Cascade Mountains. Between the boundaries here given, within the territory of the United States, lies an elevated plateau region, which consists



PROFILE OF NORTH AMERICA FROM WEST TO EAST

of three physiographic divisions: the Columbia plateau, or that drained by the Columbia River; the Great Basin, or that with an interior drainage represented by such streams as those flowing into the Great Salt Lake and the Sink of the Humboldt River; and the Colorado plateau, or that drained by the upper and middle portions of the Colorado River of the West.

A ROCKY MOUNTAIN SUMMIT — PIKES PEAK

The Rocky Mountains exhibit great variation in structure. Many of the ranges seem to have resulted from the upheaval of the older or crystalline rocks, shouldering off the stratified rocks which now rest upon their flanks in a highly inclined

position. This is especially true of the ranges facing the Great Plains. Mountains have also resulted from crushing, folding, and faulting, and the evidence of igneous action is not wanting. The magnitude of the Rocky Mountains will be better understood when it is known that within the state of Colorado alone there are 30 or more peaks each having an altitude exceeding *two and one half miles.*

The whole region of uplift has been cut and carved, worn, and remodeled by the action of snow and ice (glaciers), rain,

GATEWAY, GARDEN OF THE GODS, COLORADO

and flowing water. Thus the present form of these mountains has been wrought — the peaks, domes, and ridges. Rising above the timber line, the higher, barren, rocky summits, exposed to the wasting action of the elements, are covered with a mantle of coarse fragments — they are *rocky* mountains in fact as well as in name.

The *parks* and *gardens* are features worthy of special mention. The former are sheltered valleys, surrounded by mountains, the best known being North, Middle, South, and San Luis parks; the latter are valleys of erosion formed by the wasting

away of the softer portions of the upturned strata on the flanks of the mountains, the harder strata forming an inclosing wall. The Garden of the Gods, at the foot of Pikes Peak, near Colorado Springs, and Monument Park furnish excellent examples of the effects of erosion on strata of varying degrees of hardness.

Within the Dominion of Canada the Rocky Mountains still rise as a lofty barrier between the great central plain and the

THE BRIDGE OF SIGHS—AN EXAMPLE OF EROSION, MONUMENT PARK, COLORADO

Pacific Ocean. Here are found numerous living glaciers spreading from the snow-clad summits. Being nearer the Pacific, these mountains are more bountifully watered than the ranges within the United States, and consequently more heavily timbered.

Many large rivers have their sources in the Rocky Mountains. The Missouri and Arkansas and their numerous tributaries, together with the Rio Grande, represent the Gulf drainage. The Fraser River in Canada, the Columbia, and the Colorado have their origin on the west side of the mountains. The latter rivers are remarkable for the depth to which they have excavated their channels in their course to the sea. Plateaus and even mountains have been deeply trenched, forming the most wonderful canyon gorges in the world.

The Sierra Nevada and Cascade Ranges form the western buttress of the Pacific highland. The Sierra Nevada lies within the state of California, extending from Mount Shasta, near its northern boundary, in a southeastern direction, skirting the valleys of the Sacramento and San Joaquin rivers; the Cascade Mountains extend northward from Mount Shasta through the states of Oregon and Washington into the Dominion of Canada, following a course parallel to the Pacific coast.

The Sierra Nevada ranges have an interesting history. Originally elevated by a crumpling of the earth's crust, they were eroded until represented by mountains of very low altitude. Later they again became the scene of a great upheaval. Faulted and broken into great blocks, their crest was moved farther eastward and the rugged mass left with a steep slope facing the east and a rather moderate declivity facing the west. This second elevation was accompanied by lava floods which, issuing from great rents and fissures, coursed down the mountain sides, filling the old river channels. As a consequence of this a readjustment of the streams followed and new valleys were excavated.

Between Lake Tahoe and Owens Lake the Sierra Nevada attains its greatest altitude, culminating in Mount Whitney. To the highest portion of this region the name of *High Sierra* has been given. Here are found numerous living glaciers filling depressions or *cirques* on the north side of high summits. They are all of small size and confined to altitudes exceeding 10,000 feet above the sea level.

The Cascade Mountains were in the past the seat of extensive volcanic action. Of the many beautiful cones which crown their summit Mount Hood is probably the most conspicuous. The highest peaks, including Mount Shasta, Mount Hood, Mount Rainier, Mount Baker, and the Three Sisters, are snow-capped and support living glaciers. Here as in other regions of high altitude the upraised mass has been deeply dissected.

The Columbia Plateau is a region of lava floods. The entire area between the Rocky and the Cascade Mountains has been

literally buried beneath a vast outpouring of igneous matter, forming, when cooled, a great lava plain from which, in places, old mountain summits rise in islandlike masses. The flowing lava by obstructing the stream ways caused the formation of many lakes. Later these were drained and their deposits now form rich agricultural lands.

In its course through the lava beds, the Snake River, for several hundred miles, has excavated a deep canyon, forming a

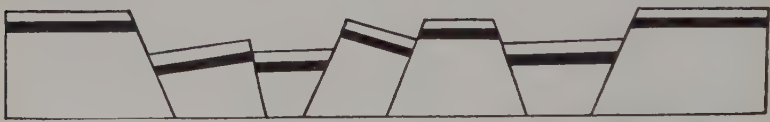
MT. HOOD FROM LOST LAKE. HEIGHT 11,225 FEET

barrier of considerable magnitude. In this gorge there are points where the irregularities of the older land surface are encountered; these have also been deeply eroded by stream wear. Near the head of the canyon the river flows over a lava precipice, forming a magnificent cataract known as Shoshone Falls.

That this region has not been entirely free from diastrophic movements is shown by the Blue Mountains, which have been formed by the breaking and upheaval of a portion of the lava plain.

The lava floods of the Columbia plateau are among the greatest known in the history of the earth. They are exceeded only by those of the peninsula of India.

The Great Basin includes a large area lying between the Wasatch Mountains and the Sierra Nevada, characterized by its interior drainage and wide-spread aridity. Its width, in an east-and-west direction, is fully 500 miles and its length 800 miles. In its northern portion it attains a general altitude of 4000 to 5000 feet, with mountains rising still higher. In its southern portions its altitude is greatly reduced, and in Death's Valley, in southern California, it is several hundred feet below the sea level. Its surface is diversified. There are large, level desert plains as well as mountains and valleys. As has been already stated, the crust of the earth has here been profoundly fractured and faulted, and the Basin ranges, trending north and



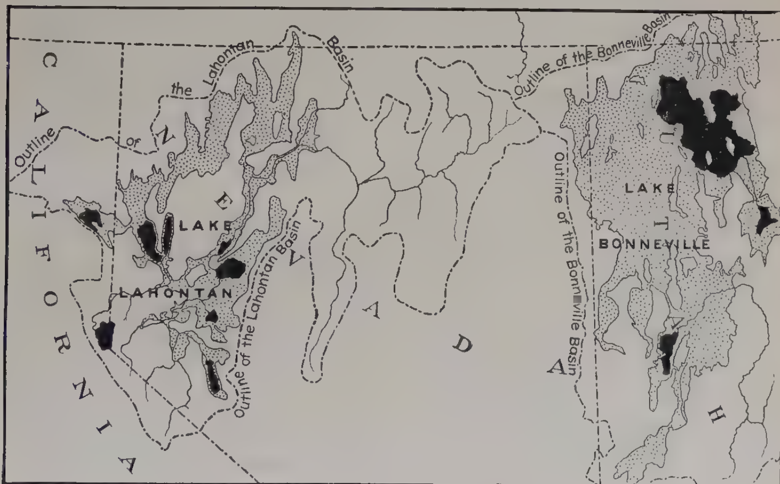
SECTION ILLUSTRATING THE STRUCTURE OF THE BASIN RANGES. After Russell.

south, have resulted from the upheaval and tilting of the long, narrow blocks. As they now rest they present a precipitous front in one direction and slope off gradually in the other. The valleys between the mountains have been deeply filled with rock waste, which, issuing from the gorges, has spread out in the form of wide fans.

The streams of the Great Basin either end in salt or alkaline lakes or are evaporated or absorbed before reaching them. During times of storm mountain torrents, upon reaching the valleys, owing to their increased volume, spread out, forming temporary lakes. These soon evaporate, and there are left mud plains, or *playas*. Such mud deposits are common in many parts of Nevada.

Formerly the amount of precipitation in this region was much greater than at present and there existed large lakes now

extinct. Their old shore lines have been traced for many miles and their old terraces and delta deposits have been carefully studied. One of these lakes, of which Great Salt Lake is a remnant, spread out over a large part of the western half of Utah. It has been named Lake Bonneville. Another extensive lake existed in the northwestern part of Nevada, of which



MAP OF PORTIONS OF UTAH AND NEVADA SHOWING THE AREAS FORMERLY OCCUPIED BY THE EXTINCT LAKES BONNEVILLE AND LAHONTAN

Pyramid, Winnemucca, Humboldt, North and South Carson, and Walker lakes are remnants. To this inland sea the name of Lake Lahontan has been given.

" The bare mountains reveal their structure almost at a glance, and show distinctly the many varying tints of their naked rocks. Their richness of color is sometimes marvelous, especially when they are composed of the purple trachytes, the deep-colored rhyolites, or the many-hued volcanic tufa so common in western Nevada. Not unfrequently a range of volcanic mountains will exhibit as many brilliant dyes as are assumed by the New England hills in autumn. On the desert valleys the scenery is monotonous in the extreme, yet has a desolate grandeur of its own, and at times, especially at sunrise and sunset, great richness of color. . . . As the sun sinks behind the western peaks and the shades of evening grow deeper and deeper on the mountains, every

ravine and canyon becomes a fathomless abyss of purple haze, shrouding the bases of gorgeous towers and battlements that seem encrusted with a mosaic more brilliant and intricate than the work of the Venetian artists."

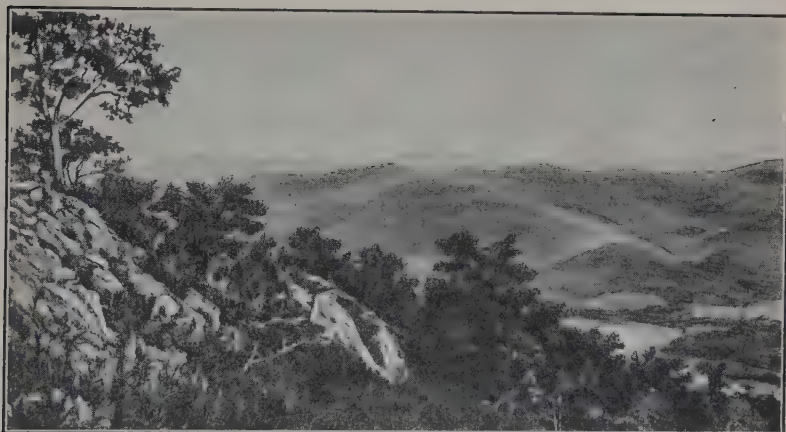
— I. C. Russell.

The Colorado Plateau occupies the region between the Wasatch and the Park Mountains. On the north it is bounded by the Uinta range and on the south it extends into Arizona and New Mexico. Through it the Colorado River has cut its canyon. Here the earth's crust has been extensively faulted, and by the upheaval of great blocks, embracing many square miles of area, minor plateaus have been formed. As these blocks have been slightly tilted, their upturned edges form scarps or cliffs, which, by the erosion of their softer layers or strata, have retreated until the plateaus in places resemble a series of steps or terraces. The higher scarps rise a thousand feet or more, and some of them follow quite closely the fault lines. That vulcanism has not been absent is shown by the occurrence of cinder cones, laccolitic mountains, and table mountains capped with igneous rock.

The Atlantic Highland comprises the Appalachian mountain system and the plateau of Labrador. It extends from Labrador nearly to the Gulf of Mexico.

The *Appalachian Mountains* in their northern course consist of a number of disconnected groups such as the White Mountains of New Hampshire, the Green Mountains of Vermont, and the Adirondack and Catskill Mountains of New York. To the southward they are composed of several well-marked and nearly parallel ranges, separated into two belts by the Great Appalachian Valley, a pronounced depression extending from Pennsylvania to Alabama. The belt lying nearer the coast is composed largely of older rocks in the form of gneisses, schists, and granites, collectively known as crystalline rocks, while the inner belt is made up of stratified rocks, much folded, compressed, and overthrust. To have produced such results it is reasonable to suppose that the force exerted must have been very great.

The Appalachian Mountains also have an interesting history. Originally elevated at the close of the Carboniferous or Great Coal-making period, they were subsequently much worn and eroded until a lowland was formed. Then, at a later period, came reëlevation with so slight disturbance that many of the old streams were able with slight modifications to retain their former courses, which now, much deepened, cross many mountain ranges.



View in the Southern Appalachians

Richland Valley from Junaluska Mountain, North Carolina. From United States Geological Survey.

Such is notably the case with the Susquehanna, Potomac, James, and New rivers. In the meantime the tributaries of these streams have been very active removing the softer and more soluble rocks, thus leaving the harder rocks in relief. In this manner, rather than by folding, the existing ridges have been produced.

The general elevation of the Appalachians is about 3000 feet above the sea, but the culminating points, Mount Mitchell, in North Carolina, and Mount Washington, in New Hampshire, are over 6000 feet high.[1]

[1] Mount Mitchell, 6711 feet; Mount Washington, 6279 feet.

THE RELIEF OF SOUTH AMERICA

Toward the interior the Appalachians are bordered by more or less dissected uplands known as the Allegheny plateau; on the seaward side they descend to the gentle undulating Piedmont belt, which, south of New England, is followed by a rather broad coastal plain.

The Central Plain extends from the Gulf of Mexico to the Arctic Ocean. The Height of Land, a low east-and-west ridge near the northern boundary of the United States, divides it into two parts. The drainage of the northern portion is to the Arctic Ocean and Hudson Bay; that of the southern portion is to the Gulf of Mexico. As the streams of the latter part are mainly tributary to the Mississippi River, it is usually known as the *Mississippi basin.*

The Mississippi basin bears a striking resemblance to a coastal plain. It occupies the site of an ancient interior sea. As the crust here has never suffered serious disturbance, there is a complete absence of the more striking features of relief. As far south as the mouth of the Ohio River this region has been subjected to glacial action (see page 269). The soils are deep and very fertile. They have originated in part from materials transported by glaciers, in part from stream and lake deposits, and in part from the wasting of rocks due to weathering. In the middle West there are large areas of prairie land, some exceedingly level, others rolling. On the east the prairies merge with the wooded region as they approach the Allegheny plateau, and on the west they pass imperceptibly into the higher or Great Plains region. Along prairie streams there is usually a rather luxuriant growth of trees and vines.

South America. — The general features of relief as exhibited by South America are similar to those of North America. There is a superior or Pacific highland and an inferior or Atlantic highland, with low central plains between them.

The Pacific highland includes the Andes Mountains, with their long, high valleys, and the lofty Bolivian plateau. The Atlantic highland, severed by the valley of the Amazon, includes the Guiana and Brazilian highlands.

By many the Andes are regarded as the direct continuation of the Pacific highland of North America, which, in crossing the Isthmus of Panama, is reduced to a series of rather low hills.

While such close relationship cannot be established between the Atlantic highlands of the two grand divisions, each includes in its make-up crystalline and the older stratified rocks.

The Andes are remarkable for their great length, equal to one sixth of the earth's circumference, for their height, and for their regularity of form. South of Aconcagua these mountains consist of a single chain, the highlands of the coast being separated from them by a broad valley. Farther south, owing to subsidence, the higher parts of the western ridges appear as islands and peninsulas. Between 27° south latitude and the equator parallel eastern and western ranges inclose valleys and plateaus,

PROFILE OF SOUTH AMERICA FROM WEST TO EAST

wonderful in height and extent, separated by transverse ranges or *mountain knots*. Of the table-lands, the Bolivian plateau is broadest and highest, and, like the Great Basin of North America, has an interior drainage. Upon it is situated Titicaca, the largest lake in South America and the highest in the western hemisphere.

North of the Desert of Atacama to the center of Colombia this great mountain system is crowned with hundreds of snow-capped peaks and studded with smoking volcanoes. For the entire distance there is not a mountain pass or gap below 12,000 feet in altitude, while the loftiest peaks exceed 19,000 feet,—Chimborazo, 20,498; Cotopaxi, 19,613; Antisana, 19,335; and Cayambe, 19,186 feet.

The northern portion of the Andes consists of three or four ranges separated by deep valleys occupied by the Magdalena River and its tributaries, which drain into the Caribbean Sea. The westernmost range, decreasing in height, blends with the Panama hills.

Very important in its bearing upon the physical geography of the continent is the singular proximity of the Andes to the western coast. Their greatest distance from it scarcely exceeds 100 miles.

CHIMBORAZO

This magnificent Andean peak rising above the valley of Quito attains the height of 20,498 feet above the sea.

The Atlantic Highlands of South America are those of Brazil and Guiana.

The *Brazilian Highland* is a broad plateau region traversed by nearly parallel ranges of moderate elevation. Their loftiest peaks are from 5000 to 10,000 feet high.

Rising above the sea on one side and above the plains on the other sides, this great triangular area, embracing 700,000 square miles, has been termed the "Brazilian Island."

Its drainage is mainly inland, to the Amazon and Plata

systems. Only one important river, the São Francisco, flows directly into the Atlantic, and then only after a course of a thousand miles behind mountain barriers.

The *Highland of Guiana* is a plateau supporting several closely set ridges, the most important of which are the Parime Mountains. Maravaca, the culminating peak, is nearly 10,000 feet high.

The Central Region of South America, like that of North America, is a well-marked depression lying between the superior and inferior highlands. It is called the Great Central Plain. It consists of the river basins of the Orinoco, the Amazon, and the Plata. These are divided by ridges so low and so narrow that the three together may not unfairly be considered as forming one great basin.

The following curious facts will show how nearly alike their level actually is. The Cassiquiare, which rises between the Amazon and the Orinoco, forks, after running some distance, and sends off one branch to the south to unite with the waters of the Amazon, the other to unite with those of the Orinoco on the north; it thus connects these two river basins by a water way that permits the Indians to pass in their canoes from either of the two great rivers into the other.

Furthermore, in the Brazilian province of Matto Grosso there are two springs side by side, and within a few feet of each other. From one the water flows into the Amazon, from the other into the Plata: and so close are the navigable waters of these rivers to each other, that, with a single portage of a few miles, the voyager, ascending the Plata from the sea, may return to the ocean again, either through the Amazon or the Orinoco.

Silvas of the Amazon.—The valley of the Amazon is not only of great extent, but it is very level. Lying within the tropical rain belt, it is one of the best watered regions of the world. This, together with the warm climate and rich alluvial soil, has been productive of remarkably dense forest growths known as *silvas*. So close together are the trunks of the trees and so great the tangle of vines that were it not for the water ways this region would be quite impenetrable, as paths are cut with difficulty. During the rainy seasons the lower portions of the valley are flooded far and wide and the waters even flow through the tree tops. On the other hand, during the dry seasons the waters so

far recede as to leave strips of meadow land exposed, their long submergence having effectually checked the forest growth.

Llanos. — West of the Guiana highland the low valley of the Amazon passes imperceptibly into that of the Orinoco, and the forest growth, so characteristic of the former, soon gives way to a treeless or prairie region. During the wet or rainy season these plains are more or less flooded, but later, when the water recedes, they are covered with a luxuriant growth of coarse grass resembling great meadows, hence the name llanos which has been applied to them. During the dry season, however, they present a very different aspect: The Orinoco no longer fills its banks, but, much shrunken, courses its way seaward; the grasses and other vegetation have withered away; the once green plains have taken on a parched and desertlike appearance; and the smaller streams have ceased to flow.

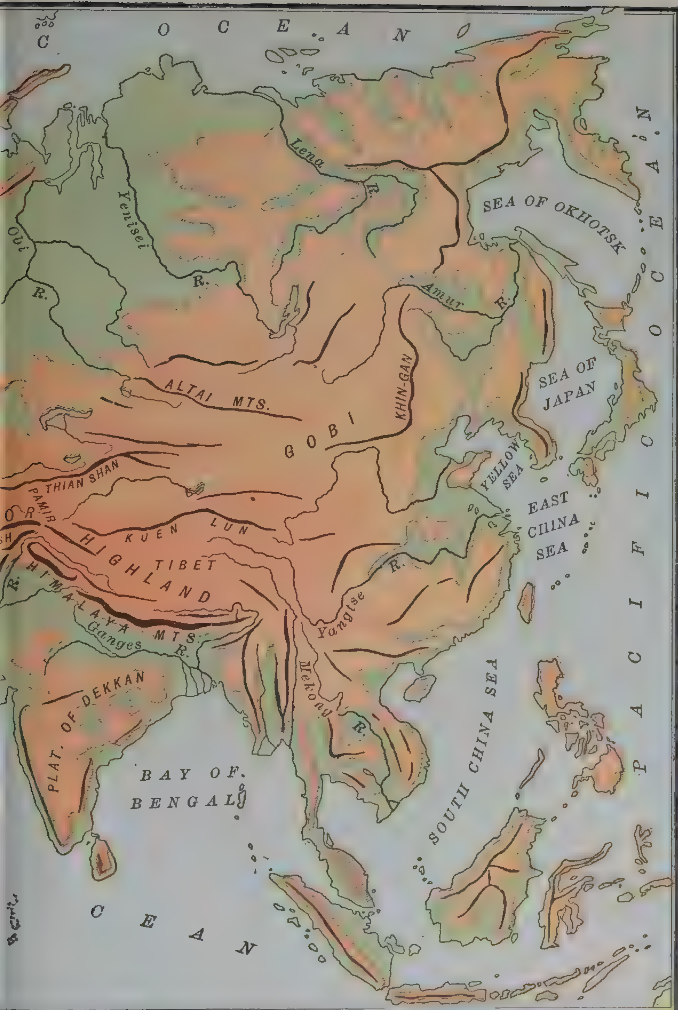
The Chaco and Pampas. — The third of the great South American basins is that of the Plata. Lying south of the Amazonian basin, it is separated from it by a low and almost imperceptible divide. Its northern portion is wooded and in its forests and swamps are found both wild animals and Indians. Famous as a hunting ground, this region is known as *The Chaco.* Roughly located, it lies west of the Paraguay River and north of the Pilcomayo.

The larger part of the basin, however, is in the form of almost level plains, although occasionally relieved by hills and low mountains. They are the *pampas.* The higher plains vary in altitude from 3000 to 600 or 700 feet. They are bordered along the Plata and the Parana by low alluvial plains.

The pampas vary somewhat in their surface features. In the south they are barren and sandy; north and west of the Cordoba Hills there are numerous saline basins, and in the region of Buenos Aires there are rich farming lands. Notwithstanding the widespread barrenness, much of the country is covered with nutritious grasses, so that the pampas of Argentina rank among the greatest grazing lands of the world.


ATLANTIC OCEAN
BAY OF BISCAY
PYRENEES
NORTH SEA
SCANDINAVIAN MTS.
BALTIC SEA
Rhine
ALPS
DINARIC ALPS
CARPATHIAN MTS.
Danube R.
Dnieper R.
Volga
BALKAN
BLACK SEA
CAUCASUS MTS.
CASPIAN SEA
Below Sea Level
MEDITERRANEAN SEA
PLATEAU OF ARABIA
RED SEA
PLATEA
OF IRAN
INDIA

THE


OCEAN
SEA OF OKHOTSK
SEA OF JAPAN
YELLOW SEA
EAST CHINA SEA
SOUTH CHINA SEA
PACIFIC OCEAN
BAY OF BENGAL
OCEAN
Lena R.
Yenisei R.
Obi R.
Amur R.
ALTAI MTS.
GOBI
KHIN-GAN
THIAN SHAN
PAMIR
KUEN LUN
TIBET
HIGHLAND
HIMALAYA MTS.
Ganges R.
Yangtse R.
Mekong R.
PLAT. OF DEKKAN

OF EURASIA

XI. RELIEF FORMS OF EUROPE, ASIA, AFRICA, AND AUSTRALIA

Europe, like North and South America, has its superior and inferior highlands and its low plain, but the arrangement of these features differs from that prevailing in the New World in two well-marked particulars: (1) the main axis of elevation extends east and west, not north and south, as in the case of the Rocky Mountains and the Andes; (2) the mountain chains do not exhibit the characteristic parallelism shown by those of the New World.

The Superior Highland of Europe stretches across the southern portion of the grand division, from the Atlantic to the Black

PROFILE OF EUROPE FROM SOUTH TO NORTH

Sea, and, if we regard the Caucasus as its eastern prolongation, it reaches the shores of the Caspian.

Beginning with the Pyrenees, its western termination, it culminates in the Alps. Eastward of the Alps it divides into two important branches, a northern, consisting of the Carpathian Mountains, and a southern, consisting of the Dinaric Alps and the Balkans. These ranges inclose the Danube basin. In addition, the Apennines of Italy and the mountains of Greece are included in this system.

The Alps, which cover an area of about 90,000 square miles, are the most celebrated of all the mountain systems in the world. Their historic and poetical associations, the grandeur and beauty

of their varied scenery, the number and extent of their glaciers, and their accessibility to travelers invest them with an interest unrivaled by the loftiest summits of other lands.

Occupying a central position between France and Germany on the north, and Italy on the south, they can be reached in a few hours from any of the great cities of Europe. Owing to

THE JUNGFRAU FROM WENGERNALP

This snow-clad Swiss summit is a most imposing sight. Its altitude is 13,760 feet. During the summer months avalanches of ice are of common occurrence, falling from the heights into the deep valley beyond the line of trees in the foreground.

their varied attractions they are visited by so many thousands annually, that they have been called, not inappropriately, "the playground of Europe."

"As we climb the Alps," says a distinguished scientific writer, "peak rises behind peak, crest above crest, with infinite variety of outline, and with a wild grandeur which often suggests the tossing and foaming breakers of a stormy ocean. Over all the scene, if the air be calm, there broods a stillness which makes the majesty of the mountains yet more impressive. No hum of bee or

twitter of bird is heard so high. No brook or waterfall exists amid those snowy heights. The usual sounds of the lower ground have ceased. Now and then a muttering like distant thunder may be caught, as some loosened mass of snow or ice falls with a crash into the valleys; or the wind brings up from below in fitful gusts the murmur of the streams which wander down the distant valleys."

The highest peaks of the Alpine system are Mont Blanc, 15,730 feet; Monte Rosa, 15,217 feet; and the Matterhorn, 14,705 feet.

The Pyrenees, which extend for a distance of about 250 miles from the Mediterranean to the Bay of Biscay, present a much greater uniformity of arrangement than the Alps. Their average height (8000 feet) is not greatly inferior to that of the Alps (8000 to 9000 feet); but their highest peak, Mount Maladetta, 11,168 feet, is far below the towering masses of Mont Blanc and Monte Rosa. The passes of the Pyrenees, however, are higher and less practicable than those of the Alps.

The Carpathian and Balkan Mountains. — The Carpathians separate the plains of Hungary from the great low plain of Northern Europe. Their greatest elevation is about 9000 feet.

Through the southwestern extension of these mountains, known as the Transylvanian Alps, the Danube River has cut a long and picturesque passage obstructed by numerous rocky ledges, the chief of which, the Iron Gate, is nearly a mile in width. The former dangers to navigation at this point have been removed by the construction of a canal.

South of the Iron Gate the mountain barrier merges with the Balkans, which, becoming an east-and-west range, is terminated by the Black Sea. The highest summits of these mountains do not exceed 7000 feet. The Dinaric Alps connect the Balkans with the Alps proper.

The Caucasus range resembles the Pyrenees in that it lies between two large bodies of water, the Caspian and the Black seas, and in the further fact that it is well defined. On the north are the great Russian plains and on the south the river Kur. The length of these mountains is about 700 miles and their width

varies between 70 and 120 miles. Mount Elburz (18,526 feet), the most conspicuous peak, exceeds Mont Blanc in height, and the entire range is high, with a snow-clad crest and glaciers. This great mountain barrier forms a part of the boundary between Europe and Asia.

Peninsulas. — High Europe throws out three mountainous projections toward the south: the Iberian or Spanish Peninsula on the west, the Italian in the center, and the Grecian on the east.

The Iberian or Spanish Peninsula is a great plateau surmounted by several parallel ranges. The Pyrenees, which are the principal of these, form the dividing line between France and Spain.

In the Italian Peninsula we find the Apennines, an important prolongation of the Alpine system. These are more famed for their beauty than for their altitude. The volcanoes of Vesuvius, Etna, and the Lipari Islands are considered as belonging to this chain.

The Grecian Peninsula, like the Italian, boasts of no very elevated ranges. Its mountains are famed less for their height than for their historic and poetic associations. They were the mythic homes of the gods of ancient Greece. The throne of Jupiter rested on Mount Olympus.

The Inferior Highlands comprise the ranges of Scandinavia and the Ural Mountains.

The Scandinavian mountains consist, for the most part, of a broadly elevated region along the western coast of the peninsula. Formerly these mountains were much higher than now and indented by many deep valleys. By subsidence these valleys have in their lower portions become arms of the sea known as fiords. As they afford safe anchorage and often extend far inland, sometimes even a hundred miles, they are commercially of great value. On such bodies of water many seaports have been established.

The Scandinavian highlands terminate in North Cape, a great bluff, nearly a thousand feet in height, facing the Arctic Ocean. This point is visited annually by many tourists for the purpose of beholding the "midnight sun."

The Ural Mountains form a natural boundary between Europe and Asia. They extend southward, along the meridian

of 60° east 1500 miles, from the Arctic Ocean nearly to the Caspian Sea.

Low Europe consists of a vast plain lying northeast of the superior highland. It is bordered on the northwest by the mountains of Scandinavia, and on the northeast by the Ural

North Cape from the West
The northern end of the Scandinavian highlands.

range. It extends from the Arctic Ocean to the Black Sea, and westward as far as the Bay of Biscay.

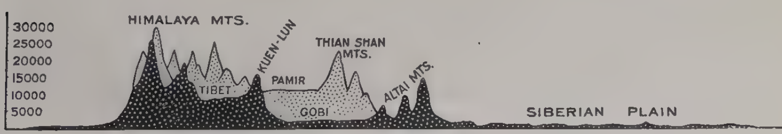
The Valdai Hills, having an altitude of about a thousand feet, mark the highest point of a swell which separates the rivers flowing into the Baltic and White seas from those which enter the Black and Caspian.

The range of this plain in latitude is so great and, as a direct consequence, its climate so varied, that it presents several well-marked aspects. The northern portion is treeless and of the general character of the lands bordering the Arctic coasts in both hemispheres. Farther south forest lands appear, which still farther south give way to rich prairie lands excepting in regions bordering the Caspian, where saline conditions prevail.

The Superior Highland of Asia consists of two portions: (1) the various mountain chains which radiate from the central elevated region known as the plateau of Pamir; and (2) the plateau of Tibet.

The Pamir is called by the Asiatics the "roof of the world." In shape it may be regarded as an irregular square. From three of its corners great chains project. The southeast corner is the starting point of the great ridges of the Himalaya, the Karakoram, and Kuen-Lun. From the northeastern corner the Thian Shan range takes its origin. From the southwestern starts the line of the Hindu Kush.

The plateau of Tibet lies between the Himalayas on the south and the Kuen-Lun Mountains on the north. It is the *loftiest table-land in the world*, having an extreme elevation of about 15,000 feet.



Profile of Asia from South to North

The Himalayan Range stretches eastward from the Pamir in an unbroken course for a distance of 1500 miles. Its breadth varies from 150 to 350 miles, and its mean height has been estimated at 6000 feet higher than that of the Andes. Over 40 of its peaks rise to an altitude of 23,000 feet, and more than 70 reach 20,000 feet. Mount Everest, with an elevation of 29,000 feet, is, so far as known, the highest mountain on the globe.

The Himalayas present the grandest possible mountain scenery; deep gorges wrapt in perpetual twilight gloom; frightful precipices; somber forests of rhododendrons and pine trees; higher up, vast glaciers filling the ravines, and ice and snow covering the ridges which rise one above another to such sublime heights as must ever secure their summits immaculate from the footsteps of man. Everything is colossal; but the Himalayas lack the smiling valleys and sheltered lakes which impart such picturesque charm to the Alps. They possess the grandeur without the amenity, the magnificence without the variety, which mark the less elevated European system.

The passes of the Himalayas, instead of leading through low gaps and over gentle declivities, rise up into the regions of perpetual snow and ice, and are so difficult as to be of little avail for the purposes of commerce between the people on the opposite sides. They are on an average 10,000 feet higher than those of the Alps, and nearly 4000 feet higher than those of the Andes. We cannot be surprised that India and Siberia are practically farther removed from each other than if they were separated by an ocean, nor even that the opposite slopes of the Himalayas are occupied by men of different races.

The Karakoram, Kuen-Lun, and Thian Shan Mountains. — The Karakoram range traverses the plateau of Tibet, and is supposed to have a greater average height than even the Himalayas. It contains Mount Godwin-Austen (height, 28,278 feet), believed to be the highest summit next to Mount Everest in the world.

The Kuen-Lun range separates Tibet and eastern Turkestan, and is prolonged by the Chinese range of the Pe-Ling.

The Thian Shan range forms the northern boundary of the plateau of eastern Turkestan. Some of its peaks attain the height of 20,000 feet.

The Hindu Kush extends in broad, massive ranges westward for 400 or 500 miles. A depression then occurs. The range, however, is really continued in the Elburz Mountains, which form the northern boundary of Persia.

The general direction of the great mountain chains of the superior highland region is east and west.

The Inferior Highlands comprise the Altai Mountains and their northeastern continuations, together with the Great Khin-Gan range, and the ranges of southeastern Asia, and, finally, the subordinate plateaus of the grand division.

The Altai and the Khin-Gan Mountains. — The Altai Mountains, extending in a northeasterly direction, are continued in the Yablonoi and Stanovoi ranges. They separate the desert wastes of Mongolia from the plains of Siberia. Some of their peaks are 12,000 feet high.

"Although far less extensive and elevated than the Thian Shan, the Altai still bears comparison with the European Alps, if not in the height of its peaks, diversity of its forms, abundance of its snow or rich vegetation, at least in the development of its ranges and the length of its valleys." — Reclus.

The Khin-Gan Mountains, with their southern offshoots, form the eastern barrier of the great Desert of Gobi.

The Plateaus of Asia are a prominent feature of the grand division. They extend in a series from the shores of the Red Sea nearly to the Pacific Ocean. In general they are arid and rainless, sandy, stony, and barren. In the spring their surface is thinly sprinkled here and there with grass and herbs, but in the summer and autumn it is, for the most part, dry and sterile.

The sheltered valleys are, however, in many cases exceedingly fertile. In such valleys there is a settled population, but outside of them the plateau region may be described as the home of roving herdsmen and marauding Bedouin.

North of the Kuen-Lun Mountains are two plateaus, eastern Turkestan and the Desert of Gobi. These are shut in on the north by the Thian Shan and Altai Mountains. The average elevation of eastern Turkestan is about 2000 feet above the sea level; that of Gobi, about 4000 feet. Entering Gobi from Tibet, we should descend fully 9000 feet.

The triangular plateau of the Dekkan in India rises to the average height of about 3000 feet. The sides of the triangle are the eastern Ghats, the western Ghats, and on the north the Vindhya Mountains.

The plateau of Iran or Persia, including large portions of Afghanistan and Baluchistan, is shut in by the Elburz and Hindu Kush Mountains on the north, by the Zagros chain on the south, and the Sulaiman on the east. It rises from 3000 to 4000 feet above the sea level.

The plateau of Armenia, with Ararat (about 17,160 feet high) for its culminating point, rises to the westward of Persia.

The plateau of Asia Minor lies westward of that of Armenia. It has an average elevation of 2500 feet. The Taurus ranges bound it on the south.

The plateau of Arabia forms the southwestern projection of Asia.

The Great Lowland of Asia lies to the north. It extends from the shores of the Arctic Ocean southward to the base of the Altai Mountains and the adjacent ranges, and comprises the Kirghiz Steppes and the Siberian Plain.

It is a part of the almost continuous depression which extends through Europe and Asia, from the North Sea to Bering Strait, a distance of more than 5000 miles.

The Kirghiz Steppes are wide and monotonous tracts, covered in spring with rough grass, parched with drought in summer, and bleak and desolate in winter.

THE DEAD SEA, PALESTINE

This remarkable salt-water lake occupies the deepest known depression of the land below sea level. Its length is 47 miles; its greatest width does not exceed 10 miles; its surface is 1292 feet below that of the Mediterranean Sea; and its greatest depth is 1310 feet. From the eastern and western margins of the sea the land rises precipitously in the form of great limestone cliffs.

The Siberian Plain consists of prairies and piny forests in its southern portions; of swampy tundras on its northern edges.

Inferior in size to the Siberian Plain, but vastly more important for their influence upon the history of the human race, are the plains of China and India. They support nearly one half the population of the globe.

Two remarkable depressions are found on this grand division. One is occupied by the Dead Sea, the surface of which is 1292 feet below the level of the ocean; the other by the Caspian, the surface of which is 84 feet below.

The Grand Division of Africa obeys less closely the general law of continental relief. It has, however, mountain ranges along the coast, while a plateau region of less elevation occupies the interior. Its superior highland, lying on the east, is broken by rivers into pronounced segments. Notwithstanding that its mean elevation is said to exceed that of Europe and even Asia, its mountains can scarcely be compared with the Alps in magnitude, much less with the Himalayas.

The Superior Highland consists of an elevated region which extends from the Isthmus of Suez to the Cape of Good Hope. One important portion of it, the plateau of Abyssinia, attains an elevation of 7000 to 8000 feet. The culminating points, however, are the snowy heights of Kenia, Kilimanjaro, and the Ruwenzori Mountains (about 19,000 feet), near the equator. South of these elevations occur the Livingstone Mountains (5000 to 10,000 feet), walling in Lake Nyassa; and nearly at the southern extremity of the continent lie the Snow Mountains, which may be considered as vast terraces ascending from the sea toward the interior.

The plateau of Abyssinia has been described as a "block" of the older crystalline rocks, gneisses, and schists, capped with lava sheets. Its surface has been profoundly eroded, and in places the accumulation of volcanic matter is said to form high mountains. Lake Dembea occupies a depression 3000 feet below the general level and is regarded as the chief source of the Blue Nile.

The Inferior Highlands include the ranges which border the northern and western coasts. The Atlas Mountains on the north consist of three or four parallel ranges which ascend from

THE RELIEF OF AFRICA

the Mediterranean stage by stage, and increase in height to the westward.

The Kameruns and the mountains near the headwaters of the Niger are the principal elevations on the west. The Kameruns are volcanic. They attain at some points the height of nearly 13,000 feet.

The Interior of the grand division may be regarded as a vast plateau bordered by the various coast ranges. Low plains are to be found only along the coast.

A CARAVAN ON THE DESERT OF SAHARA

The plateau region may be divided into two sections: (1) that portion which consists of prairies and fertile river basins; and (2) the arid Sahara.

The Sahara stretches east and west 3000 miles, north and south

SCENE ON THE DESERT OF SAHARA

1000, covering an area of $2\frac{1}{2}$ millions of square miles. It is not an absolute level. Its average elevation is about 1200 feet, but it contains areas which are 4000 or 5000 feet in height, and has a mountain range one of whose peaks is nearly 8000 feet

THE RELIEF OF AUSTRALIA

high. Southward of Tunis are found depressions, some of which are 100 feet below sea level. They are marshy regions for most of the year, but when the winter rains fall they receive the drainage from the mountains, and thus become broad, open lakes known as chottes (*shots*). The surface of the desert consists, in some places, of sharp stones, in others of gravel, in others again of shifting sand. The latter when driven before the wind is arranged in long, huge billows called *dunes*.

Here and there over the desert are found fertile spots or *oases* where water may be obtained either from springs or wells.

Australia somewhat resembles Africa in its relief. It has an elevated border and a depressed interior.

The superior highland lies along the eastern and southeastern shores. It includes the Blue Mountains and the Australian

Alps, culminating in the latter, the loftiest peaks of which are about 7000 feet high.

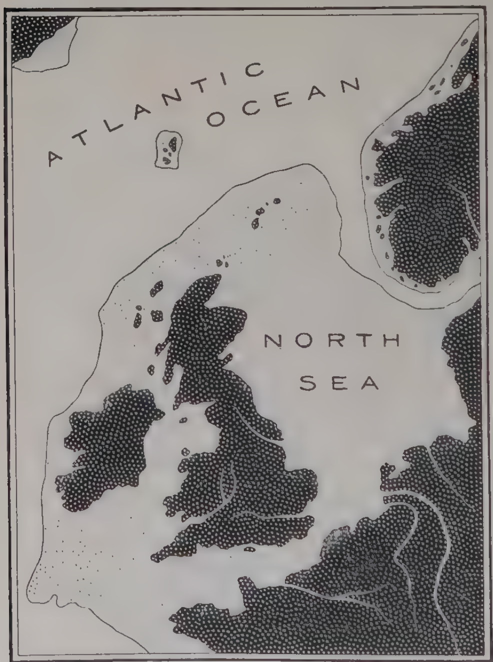
INSPIRATION POINT, BLUE MOUNTAINS, NEW SOUTH WALES, AUSTRALIA
Photographed by Sterling R. Fulmore.

The inferior highland borders the western and northwestern portions of the continent.

Of the central lowland the basins of the Darling and Murray rivers are best known. Of the remainder much is desertlike. A characteristic feature of the lowland is its inland salt lakes, which cover large areas during the rainy season, but shrink to saline marshes or completely disappear during the dry season.

XII. ISLANDS

Classification. — As distinguished from continents the smaller land masses rising above the sea are termed *islands*. They vary greatly in size, from the mere protrusion of a rocky or low-lying mud or sand bank, a few square feet in area, to land masses hundreds of square miles in extent, which, in their general characteristics, are not unlike the continents themselves.

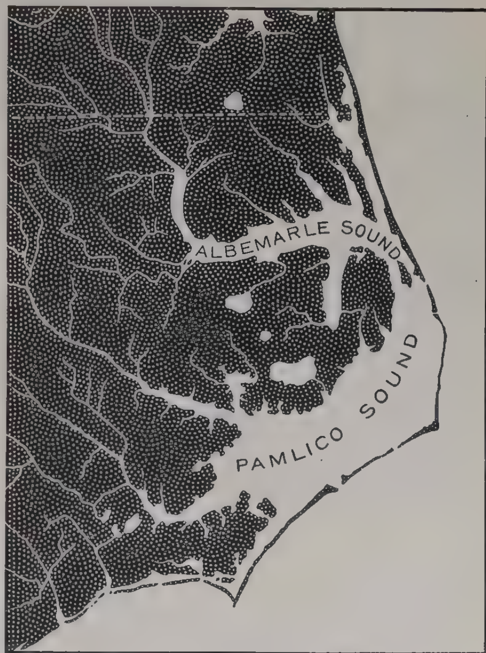


THE BRITISH ISLANDS AND THE SUBMARINE PLATFORM ON WHICH THEY REST. After Geikie. The tinted area is less than 100 fathoms in depth.

According to their origin and structure islands may be classified into two groups: (1) *continental*; (2) *oceanic*.

Continental Islands, as their name implies, rise from the submerged continental borders and not from the deeper parts of the ocean's floor. At earlier periods in the earth's history many of them were actually parts of the continents from which they have been separated by settling (subsidence), wave wear (erosion), or a combination of both.

Sea exploration and soundings show that the British Islands rest upon a submarine platform which cannot be regarded as other than an extension of the mainland of Europe. This, together with their geologic structure, goes to show their intimate relation to the existing continent, of which, in fact, they form a part.



MAP OF THE COASTAL PORTION OF NORTH CAROLINA

In this partially drowned region the outer sand reefs, in the form of long, narrow islands, almost completely close the entrances to Albemarle and Pamlico sounds. The inclosed bodies of water are being gradually filled by the silt and sand brought from the land by river action.

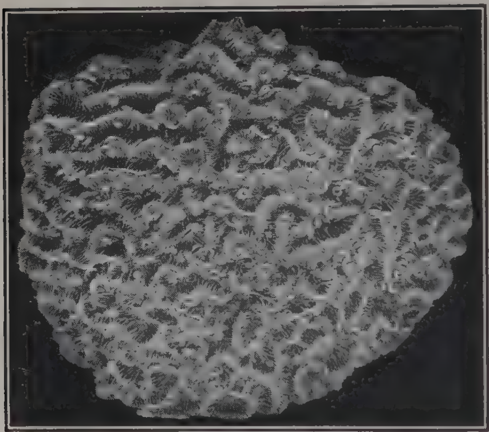
Other coastal islands have resulted from the *constructive* action of the waves by which mud banks, sand spits, and reefs have been thrown up. Once above the water, their growth is aided by the springing up of coarse grasses and other forms of vegetation which gradually collect and hold in place additional matter.

Along the Gulf coast of Texas long barrier islands, broken by occasional inlets, have been built up by the waves driven shoreward by the prevailing winds. The filling up of shallow sounds and the present growth of islands is also well illustrated along the coast of North Carolina.

Oceanic Islands are situated far from the continents. They rise from the deeper portions of the ocean's floor. In structure they are strikingly unlike most continental islands, being either *volcanic* or *coralline.* The former often rise thousands of feet

above the sea level, while the latter are low-lying and devoid of surface relief.

Oceanic islands of the first group are the tops of volcanic peaks which rise above the sea through their own upbuilding; the islands of the second group are brought to the surface by the upbuilding of coral reefs from high submarine volcanic or other platforms.



BRAIN CORAL

In this figure there is shown a coral skeleton, that is, "dead coral," which is composed of carbonate of lime, the substance of limestone. The living portions of coral, the polyps, are soft and fragile, and when removed from the sea water soon dry up and disappear.

Volcanic Islands are arranged, as a rule, along the great bands or belts of volcanic activity which traverse the globe.

Most of them are found within the volcanic belts of the Pacific and the Atlantic. There are, however, exceptions to this general rule, many volcanic islands being situated quite irregularly. The volcanoes upon islands in the Pacific belt are among the most active in the world; those in the Atlantic belt are far less active, and many are either extinct or bordering on extinction.

Volcanic islands are formed by the accumulation of materials thrown out by submarine volcanoes. Sometimes such islands are formed very suddenly, as in the case of Graham Island, in 1831, and that off the island of Santorini, in the Mediterranean, in 1866.

Coral Islands are found especially in the southern Pacific and Indian oceans. They are a result of coral growth and wave action. The coral animal is a *polyp* — not an insect, but an

animal much lower in the scale of life — which secretes from sea water a skeleton composed of carbonate of lime, the substance of limestone. Many polyps are usually supported in common by a single skeleton, which may be of a delicate branching form or a great rounded mass or head. Beginning in water not exceeding 20 C.F.T. fathoms, more often 6 or 7 fathoms, the reef-building coral by the growth and accumulation of its hard parts lays the foundation of what may become a reef or a coral island. In all cases this coral growth rises from a submarine platform which not infrequently is the submerged summit of a volcanic peak. Polyps thrive best when immersed in pure sea water; accordingly they exhibit the greatest profusion on the exterior or seaward side of a reef. As they approach the surface, the finer and more delicate skeletons are broken by the dashing of the waves, and their fragments, settling down among larger coral heads, fill the interstices and serve eventually to cement and solidify the reef. Finally the level of low tide is reached and the upward growth of the polyps is checked.

The further upbuilding of the reef now becomes the work of the waves — a work of destruction and of construction. Portions of coral growth are torn from their beds, broken up, ground as sand on a beach, and swept into a long ridge.

The ridge, heaped up by successive additions of broken coral, finally becomes so high that it overtops the waves, and an island is formed.

The next stage is the appearance of vegetable life. Floating wood lodges among the coral fragments. It decays and forms mold. Seeds, such as cocoanuts, not injured by salt water, are wafted to the newly formed islet; others may be carried thither by birds. Under the stimulus of a tropical sun they grow, and in time cover the dead coral mass with living green.

The breadfruit and cocoa palm are the most important of the forms of plant life that flourish upon such islands. No large animals live upon them, and, on account of their small areas, they can sustain only a limited population.

Coral Reefs may be classed as (1) fringing reefs; (2) barrier reefs; (3) atolls.

Fringing reefs occur near the shore line surrounding islands or skirting the coasts of continents. Many Pacific islands furnish examples of such reefs, as well as the eastern coasts of Africa and South America within the equatorial belt.

Barrier reefs are quite like fringing reefs, but farther removed from the land. They represent a later stage of reef development when, by the action of the waves and the growth of coral, the reef formation has advanced seaward. In the meantime the inner side of the reef has been slowly dissolving away, leaving an ever-increasing interval of shallow water between it and the land. In some instances it is possible that fringing reefs may have been transformed into barrier reefs by the gradual subsidence of the sea bottom, whereby the reef, growing upward to the surface, appears at a considerable distance from the shore. This is illustrated by the diagrams on page 133.

ATOLL

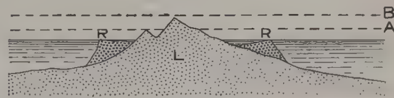
The great barrier reef off the northeast coast of Australia is 1250 miles long and from 10 to 90 miles wide. The island of New Caledonia and many others are protected from the sea by similar reefs.

An *atoll* is a belt or strip of coral reef inclosing an expanse of water called a *lagoon*.

Atolls are usually nearly oval or circular, but in many cases they are quite irregular in shape. Sometimes, as in the case of Whitsunday Island, they are complete rings; but most frequently on the side not exposed to the prevailing winds there are one or more breaks, forming inlets.

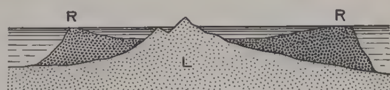
Diagrammatic Illustrations of the Formation of Barrier Reef and Atoll

I



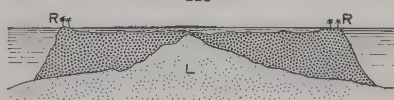
L, Section of mountain rising above water, forming an island; *RR*, section of fringing reef resting on slopes; *A*, height of sea level as shown in II below; *B*, height of sea level as shown in III below.

II



L, section of mountain rising above water after partial submergence; *RR*, sections of barrier reef resting on slopes.

III



L, section of same mountain after complete submergence; *RR*, sections of same reef now forming an atoll.

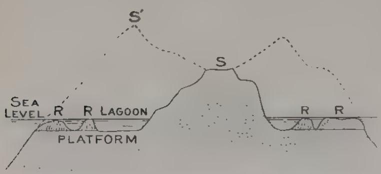
The atolls are almost innumerable. There are nearly a hundred of them in the Dangerous Archipelago, which lies to the westward of Tahiti. They are not more than half a mile across, from the sea to the lagoon. In their highest parts they are only a few feet above the water; still, they resist the utmost fury of the waves. They are thickly covered with vegetation.

Origin of Atolls. — Many of the reefs and atolls rise from very great depths; but the polyps are most vigorous in water not deeper than 60 feet; and in water that is more than 150 feet deep they cease to live. The question, therefore, arises, how can the foundations have been laid for certain reefs and atolls, which stand in water not less than a mile and a half deep?

Darwin suggested an answer which enables us to understand not only how atolls in deep water may have originated, but also how atolls in general have been formed. It is well known to geologists that the level of the ocean bed is subject to change. It may be upheaved, or, again, it may subside. Darwin conjectured that as fast as the coral reef was built up toward the

surface, it was carried down by the subsidence of the ocean bed.

Let us notice the successive steps of this process. There is reason to believe that in those parts of the ocean where atolls now abound, high mountains once towered. These mountains were islands. The polyps built encircling reefs around them. But in many cases, as they built up, a gradual subsidence took place, until the islands themselves disappeared beneath the waves. This subsidence, on the one hand, and this building up, on the other, may have continued for ages, and to the extent of thousands of feet, so that where the mountains then were, there may now be deep waters and low atolls. Thus the mountain tops were replaced by the lagoons, and the encircling reefs became coral islands.



THEORETICAL SECTION OF AN ATOLL
RR, reef; *S*, summit of island; *S'*, former summit of island.

Tahiti affords an illustration of this process. It is a volcanic island with a fringing reef, the foundations of which rest upon the submarine slopes of the island. It exhibits the appearance which must have been presented by existing atolls before the subsidence of the ocean floor had carried down beneath the surface of the sea the mountainous islands formerly inclosed by them.

Other views, however, have been advanced, among them those of Sir John Murray of the Challenger Expedition, showing that in the explanation of the origin of barrier reefs and atolls *subsidence is not necessary*.

Through wave action any summit rising above the sea may be leveled so as to form a submarine platform upon which a reef may secure a foundation. If the eminence, usually a volcanic peak, is not completely leveled, there remains an island surrounded by a barrier reef. This reef is all the time broadening its foundation by the addition of its own waste and thus pushing outward into the deeper water. Should it take on an annular form, inclosing a lagoon, with or without an island, it forms an

atoll. Such a coral island has resulted from simple reef building without subsidence. Murray entertains the view also that the lagoon may be deepened by the solvent action of sea water upon the dead coral.

Distribution of Coral. — The reef-building polyps are confined to tropical waters which have a temperature of not less than 68°. The central part of the Pacific Ocean is the scene of their greatest activity. They are also found in many portions of the Indian Ocean, in the Red Sea, and the Persian Gulf.

Except among the West Indies, at the Bermudas, and off the coast of Brazil, there are none in the Atlantic.

The area within which they are at work is not less than 25 millions of square miles.

PART III. — THE WATER

XIII. PROPERTIES OF WATER

Composition and Properties of Water. — Pure water is composed of two gases, oxygen and hydrogen, united in the proportion of one volume of the former to two volumes of the latter. It is represented by the chemical symbol H_2O.

Among the properties of water that especially interest the geographer are the following:

(1) It changes its forms with remarkable readiness;
(2) it expands when passing into the solid state;
(3) it has great capacity for absorbing heat;
(4) it has great solvent power.

Forms of Water. — Water exists in three forms or states: the solid, the liquid, and the gaseous. Changes of temperature of ordinary occurrence cause it to pass from one to another of these. As a solid it may fall gently as snow, muffling the young plants and screening them from the biting winds of winter, or as ice it may cover the surface of lakes and rivers, protecting aquatic forms of life as snow does the plants and insects of the land. As a vapor it passes off from the surface of the seas, lakes, and rivers, and even from the land itself, into the atmosphere. Mantling the earth with an invisible screen, it prevents the too rapid escape of its warmth at one time; or, assuming the form of clouds in the sky, shields it from the too great heat of the sun at another, and when still further condensed it falls as rain, supplying water to springs and rivers and necessary moisture to animals and plants.

Expansion of Water. — Water expands when passing from the liquid state to the solid. This is probably due to the fact that its particles, when crystallized, do not fit so closely together as

before. When cooled, it follows the general law, and contracts until it reaches the temperature of 39.2° F. Below this it disobeys the general law, and expands till it reaches 32°, its freezing point. Then suddenly it hardens into ice, and attains its maximum expansion.

Since ice is more expanded than water, it is lighter than water, and, as we all know, floats. Were ice heavier than water, it would sink as fast as it was formed, and our river channels and shallow lakes would be filled with solid ice from the bottom to the top.

Another important consequence of the expansion of water when freezing is that it exerts a force that is practically irresistible. It sunders the solid rock from the foundations of the mountains, and crumbles it into fragments.

Interesting examples of the effects of the force exerted by freezing water may be found on rocky hillsides. During thaws the crevices of rocks become filled with water. As the weather grows cold, this water freezes and splits the rocks.

Iron water pipes are sometimes burst by the freezing of the water in them during extremely cold weather.

Capacity of Water for Absorbing Heat. — Two effects may be produced by the application of heat to a body: (1) a rise of temperature which is generally accompanied by expansion of the body; thus an iron rod placed in the fire grows warm, and at the same time becomes longer and thicker; (2) a change of form; in this case the heat given to the body changes it from a solid to a liquid, or from a liquid to a vapor, without altering its temperature.

We are familiar with the fact that a kettle of boiling water may be kept boiling for a long time before all of the water is changed into vapor, yet during that time its temperature has not changed, although it has absorbed a large amount of heat. If the vapor thus formed be condensed to a liquid, it may be shown experimentally that the same amount of heat will be given out as was originally absorbed.

Heat which causes change of form without altering the temperature is called *latent heat;* that which is absorbed by a solid

when melting being known as the *latent heat of melting*, and that which is absorbed by a liquid when becoming a vapor, as the *latent heat of vaporization.*

Take a lamp which affords enough heat to raise the temperature of one pound of water 1° a minute and let us call that amount of heat a *unit of heat*. Now set in a vessel over the lamp a pound of ice at 32°. It will immediately begin to melt, but the heat does not warm the ice or the water; it only melts the ice. At the end of 143 minutes all the ice will be melted, but the temperature of the water will still be 32° and no more. Now, what has become of all the heat received from the lamp during these 143 minutes? It has gone to convert the solid into a liquid and is therefore called *latent*. The latent heat of melting ice is therefore 143 units. Now let the lamp continue burning as before. In 180 minutes the temperature will be raised from 32° to 212° and the water will then begin to boil. 180 units of heat have therefore been required to raise the temperature of the water from its freezing point to its boiling point. If now the boiling water be kept over the lamp it will not become hotter but will gradually change into vapor and at the end of 966 minutes more it will have boiled away. Thus the latent heat of evaporation of water is 966 units. In other words it takes as much heat to melt one pound of ice as it would to heat 143 pounds of water one degree, and as much heat to change one pound of boiling water into vapor as it would to heat 966 pounds of water one degree.

Water is peculiar in that its latent heats of melting and evaporation are larger than those of any other substance and this is of special importance in its relation to natural phenomena.

Evaporation and Condensation. — From the above statement it will be seen that evaporation exerts a cooling influence because ice or water on becoming vapor renders heat latent.

Condensation of water, on the other hand, exerts a warming influence. As has been frequently noticed, the intense cold is mitigated just before a snowstorm. This is due to the condensation of vapor into snow.

It has been computed that from every cubic foot of vapor condensed, and frozen into snow, heat enough is set free to raise more than 100,000 cubic feet of air from the temperature of melting ice to summer heat.

Nature makes great use of these counter properties, the evaporation and condensation of water. She stores away the heat of

the torrid zone among the particles of vapor, thus cooling the atmosphere. Transported by winds to other regions, they are there condensed into rain and their heat set free to warm the air and modify the climate.

The Solvent Power of Water is another property of great importance. The forms of plant and animal life are largely built up of materials which enter them in solution. Water acts as a vehicle for conveying these materials into the living system. It is essential, therefore, to the maintenance of life.

Moreover, by the solution of mineral substances water promotes rock decay and the general disintegration of the earth's crust. All waters percolating through rocks or flowing upon the surface are more or less charged with mineral matter held in solution.

Circulation of Water. — The readiness with which water changes its form and passes from the liquid state to that of vapor, and from the vaporous to the liquid state again, is the means whereby a constant circulation is carried on from the sea to the land, and from the land to the sea again.

It waters the thirsty lands; it fills the springs and replenishes the rivers. Thus some portions of the rainfall find their way back to their home in the sea through river channels; other portions, evaporated, rise in the atmosphere and again being cooled descend as rain or snow.

And thus most of the waters of the globe come out of the sea as from a reservoir and to it they are later returned.

XIV. WATERS OF THE LAND

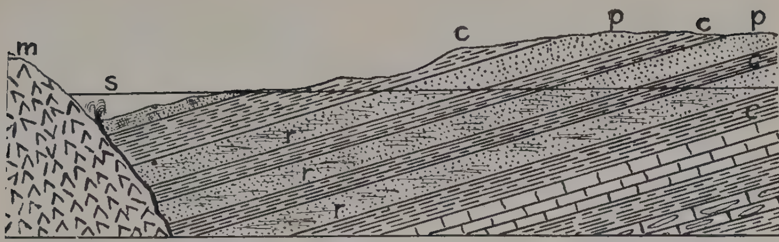
Ground Water and Springs. — Only a portion of the rain which falls upon the land finds its way directly into the creeks and rivers leading to the sea. The larger part sinks into the earth,

DIAGRAMMATIC ILLUSTRATION OF A COMMON OR GRAVITY SPRING

a represents an impervious layer above which are the porous beds *b*, *c*, and *d*. Rain water percolating the soil and porous beds appears as a spring *s*, where the bed *a* is cut by the valley.

where it is known as *ground water*, though sooner or later much of it again reaches the surface, chiefly in the form of springs. Many rocks are porous, and most rocks are traversed by cracks and especially by joints, consequently surface water percolates downward until its further progress is impeded by an impervious layer. Flowing, now, over the top of that layer in the direction of its inclination, the water will appear as springs, or a line of seepage, wherever the topography is such as to furnish an outcrop, as on the side of a hill or valley.

Should the rocks be alternately porous and impervious and incline or dip toward a fault fissure appearing at the surface at a lower level than their outcrop, then, under certain conditions, as when the opposite wall of the fissure is composed of compact or non-porous rock, the water will completely fill the fissure and will be forced out at the surface under more or less pressure.



DIAGRAMMATIC ILLUSTRATION OF A FISSURE SPRING

In the figure above the porous beds *p,p* and the impervious beds *c,c,c*, outcropping on the right and dipping to the left, on account of a fissure of displacement or fault, abut on an impervious mass *m*. The rain falling upon the outcrop creeps downward through the pervious beds *p,p* until the fissure is reached, where the water is forced to the surface as a spring *s* by the pressure of that in the reservoirs *r,r,r* behind it. As will be shown later, the principle is identical with that of the artesian well.

AN APPALACHIAN MOUNTAIN SPRING

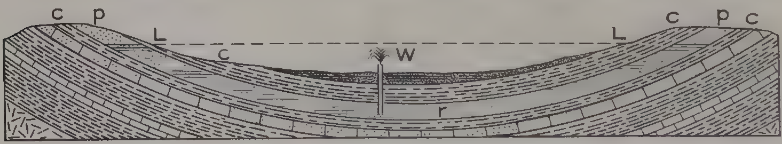
This beautiful spring, surrounded with ferns and other forms of vegetation, is one of many on the Black Mountains of North Carolina. From United States Geological Survey.

The springs above described represent two types: (1) *common* or *gravity* springs; and (2) *fissure* springs.

The depth to which percolating water descends is surprising. From a deep well sunk in a certain district of France, pieces of leaves were thrown up by the first gush of water from a depth of about 400 feet. These leaves were comparatively fresh. They were ascertained to have come from a distance of about 150 miles from the spring.

From the percolation of water through the earth arises one of the greatest difficulties in mining operations. Before the invention of steam pumps many coal pits in England were abandoned because, as the miners said, they were *drowned*. From the Comstock mine 3,500,000 gallons of hot water had to be pumped every 24 hours.

Artesian Wells are so called from the province of *Artois* in France, where they were first used. As in the case of fissure



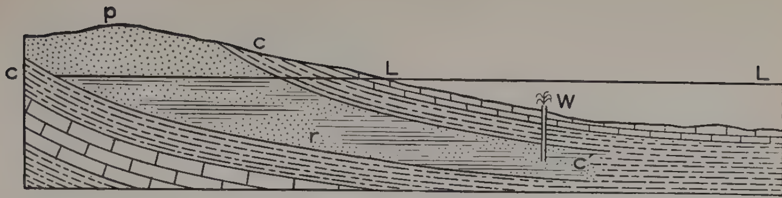
SECTION OF AN ARTESIAN BASIN

p, *p*, porous beds; *c*, *c*, impervious beds above and below *p*, *p*, inclosing the reservoir, *r*; *L*, water level; *W*, artesian well.

springs, their source of supply is porous, usually sandy, beds inclosed by impervious layers. The porous beds act as reservoirs, and their outcrop may be many miles distant from the region in which the wells are sunk. Formerly it was thought that artesian conditions prevailed only in basins, as illustrated in the figure above, and that when the upper confining layer was penetrated by boring, the water should rise, fountainlike, in the air. Theoretically it should reach the height of the water level in the reservoirs, but practically, on account of adhesion, friction, and the resistance of the air, this is not attained.

It will be readily understood that the larger the number of wells sunk in a given basin, the more the pressure is reduced by the increased outward flow which lowers the height of the water in the reservoir.

It must be kept in mind that by "reservoir" is not meant a cavity filled with water, but a porous rock, as a bed of sand or gravel, saturated with water. Through such a reservoir water flows which has fallen on its outcrop as rain.



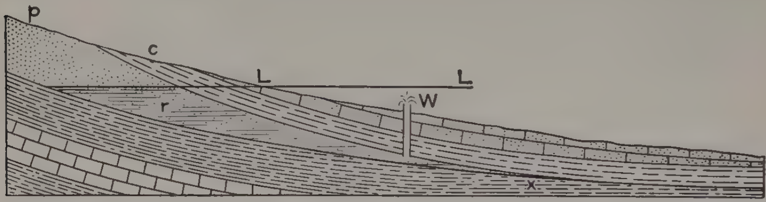
ARTESIAN CONDITIONS ARISING FROM THE PASSAGE OF POROUS WATER-BEARING BEDS INTO IMPERVIOUS BEDS

p, porous beds; *c*, *c*, impervious beds above and below the porous water-bearing beds inclosing the reservoir; *c′*, the region where the pervious beds gradually pass into impervious beds; *r*, reservoir; *L*, *L*, water level; *W*, artesian well.

It is now well known that a complete basin does not furnish the only artesian condition. Beds inclining or dipping in one direction may gradually pass from a porous into a compact and more impervious state, and if inclosed, as in the preceding case, a reservoir may be formed as indicated in the figure above, from that part of the confined beds which is porous. This reservoir likewise, when penetrated, will furnish flowing wells until by over-boring the pressure is reduced. Moreover, the same results may be attained by the penetration of inclined porous beds properly inclosed,

ARTESIAN WELL AT WOONSOCKET, SOUTH DAKOTA
The height of the column is 97 feet. From United States Geological Survey.

which thin out and disappear at some point beyond the artesian area, as in the figure below.



ARTESIAN CONDITIONS ARISING FROM THE THINNING OUT OF WATER-BEARING BEDS

p, porous beds thinning out at *x*; *r*, reservoir; *L*, *L*, water level; *W*, artesian well.

Although originally applied to flowing wells, the term *artesian* is not now so restricted, but may be applied to any deep well, whether flowing or not, which has its source at a considerable depth below the surface and depends upon the rainfall at a more or less distant point.

Artesian wells have been of the greatest value in many countries, especially in arid and semiarid regions, where they have furnished water not only for drinking purposes, but for irrigation as well. In Algiers through borings put down by the French an abundance of water has been obtained on the margin of the Sahara.

In many parts of the United States artesian wells are in common use, especially in California and Texas. In some instances the water is obtained from beds dipping beneath the sea as on the Atlantic and Gulf coasts.

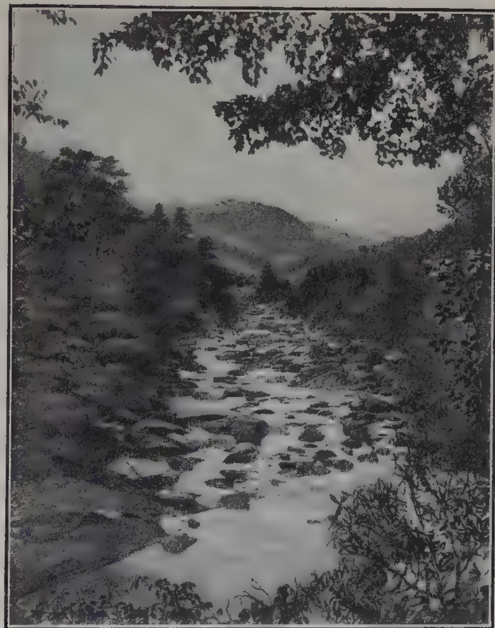
Rivers receive their waters (1) directly from the rainfall as it runs off the surface in the form of wet-weather tributaries; (2) from springs; (3) from the melting of snow fields and glaciers.

Most rivers are said to originate in springs, each of which pours forth a contribution in the form of a little streamlet. Influenced by gravity, streamlets seek a lower level, and uniting, form creeks and rivers the volumes of which are often greatly increased by sudden rainfalls and the melting of snow over a large area. In a similar manner a number of tributaries blending together make one great water course. Such a water course, with its tributary streams, is called a river system.

Erosion means the eating or wearing away of the materials

which form the earth's exterior. This is brought about chiefly in two ways: (1) by the solvent power of the water; and (2) by its mechanical action when in motion. These two combined remove the more soluble and softer rocks with ease; and even the hardest cannot withstand their action.

If the soluble particles of a rock are dissolved by water, the rock disintegrates and crumbles away. When, therefore, a stream runs incessantly over such a constantly dissolving and disintegrating rock, it is clear that erosion will make rapid progress. Moreover, the rocky fragments torn from the stream bed by the mechanical action of the flowing water, especially where there is a marked descent, are whirled against one another and the bottom and sides of the channel.



Characteristic Bed of a Mountain Stream

Hickory Nut Creek, North Carolina.

Thus as the river flows on, the fragments of rock become smaller and smaller. In the upper course of the river they may be of considerable size, but in the lower course they are reduced to sand and silt.

The erosive action of rivers is most impressively illustrated by the excavation of rocky gorges. That of the Niagara and the canyons of our Western rivers are perhaps the most striking examples that can be offered.

The Falls of Niagara, it is evident, were at one period about seven miles

lower down the stream than at present. The vast volume of water that passes over the cliff, now falling from the height of 160 feet, both directly and indirectly is a powerful eroding agent. By it the gorge has been cut backward from the Ontario scarp towards lake Erie.

Transportation. — The finer particles of eroded matter are carried along by the river in suspension; that is, simply mixed with the water. The coarser portions are rolled onward by the current. This twofold action constitutes *transportation.*

A river will transport eroded matter to a greater or less distance, and in greater or less quantity, in proportion to the velocity and volume of its current. Water moving at the rate of eight inches per second will carry along ordinary sand. If the velocity be increased to 12 inches, it will roll along fine gravel, while a current having a speed of three feet a second can sweep along pieces of stone as large as eggs. In floods masses of rock as large as a house have been moved.

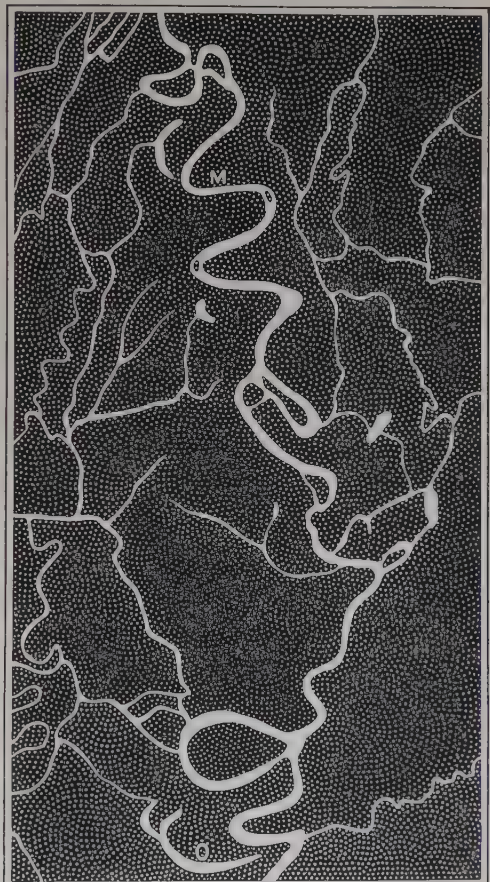
As to the quantity of matter transported, it is estimated that of visible sediment the Rhone carries into the Mediterranean more than 36,000,000 tons annually, and of salts invisibly dissolved, more than 8,000,000 tons. The amount of silt carried into the Gulf of Mexico by the Mississippi in one year would make a column one mile square and 241 feet high, and if the sand and gravel urged along the bottom be added, 268 feet.

The removal of this matter from the surface of the valley reduces its average level one foot in 4638 years.

Deposition. — The materials borne or rolled along by rivers are deposited at various points in the channel. The finer portions, called silt, familiar to us as muddy slime, are carried down as far as the mouth of the river. Farther up the stream sandy particles come to rest; still higher, gravel is deposited; and finally, in the upper course of the river we find stones of greater or less size.

It is obvious that deposition will depend very largely upon the slope of the river bed and the rapidity of the current. Anything that checks the latter favors deposition.

Changes in river courses are a frequent effect of deposition. They occur especially in rivers that flow through alluvial lands. Very often the course of such streams is marked by what are termed *meanders*, or sharp curves resembling the letter S. The lower Mississippi presents a striking illustration of this. In some cases portions of the land are carried from one side of the river to the other, giving rise to important questions of ownership.



MEANDERS, *M*, AND OXBOW LAKES, *O*, OF THE MISSISSIPPI

Sometimes, too, when a river is unusually high, it may cut for itself a straight course instead of following its old curves. The portion of the former channel that is thus abandoned, closed by silt at each end, becomes a lake, crescentic in shape, commonly called a "cut off" or an oxbow.

Among the important deposits of rivers are those that occur at or near their mouths, whether they flow into the sea or a lake. Here the current is checked by contact with the larger body of water, and, as a consequence, the silt which is readily

held in suspension by the moving water, now settles to the bottom. In this way *bars* are formed.

The Mississippi, and all the rivers of the United States that flow directly into the Atlantic Ocean, have bars.

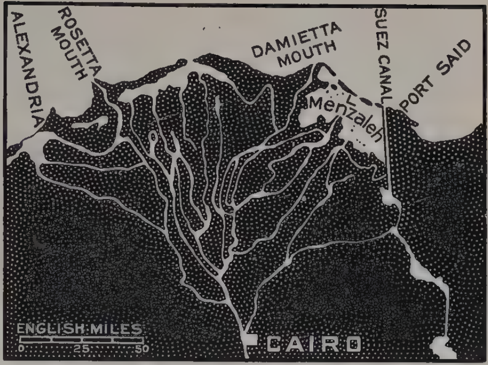
A Meandering Stream, Crooked Creek, California

Crooked Creek is a tributary of Owens River in eastern California. Its valley has been cut in volcanic rocks. In the waste-filled portion the stream has taken on the meandering condition of maturity. The manner in which such streams broaden their valleys is well shown by the meander extending to the left from the center of the picture. From photograph by Willis T. Lee, United States Geological Survey.

So great is the amount of solid matter brought down by the Mississippi that a bar no less than two and a quarter miles in breadth was formed off one of its outlets called the South Pass. Fleets of vessels more than 50 in number might sometimes be seen, detained on the bar for weeks, waiting for a chance to go to sea, or to enter the Pass. The operation of towing a ship into the deep waters of the Gulf occupied days, and in some cases weeks.

In 1875 Captain Eads, by the authority of Congress, constructed *jetties*, or long walls, which narrowed and confined the current, and thus gave it greater velocity, and, of course, greater power to scour out the channel and carry off the sediment into deep water. The mouth of the Danube has been deepened by jetties so as to admit vessels of 20 feet draught.

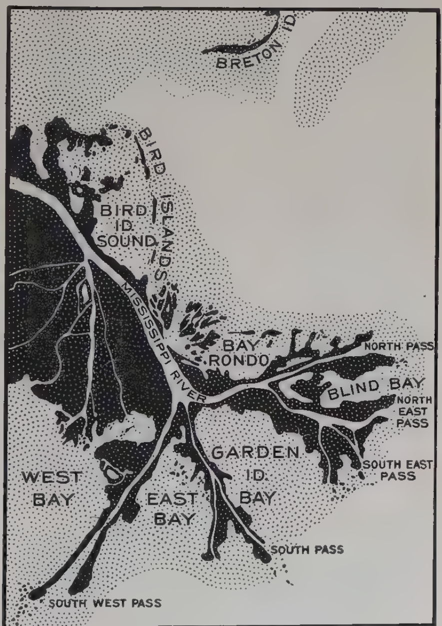
Again, when a river encounters a lake or other body of still water, where the silt deposited is not washed away by strong currents, there is gradually built up a fan-shaped deposit, through which, later, the stream may flow in several channels or *distributaries.* Such a deposit, from its resemblance to the Greek letter (Δ) of that name, is called a *delta*.



THE DELTA AND DISTRIBUTARIES OF THE NILE

The delta of the Nile has the typical Δ-shape.

The Mississippi, the Nile, the Ganges, the Orinoco, the Danube, the Volga, and many other rivers which flow into inland seas or gulfs protected from the sweep of the tides and ocean currents, are famous for their deltas.



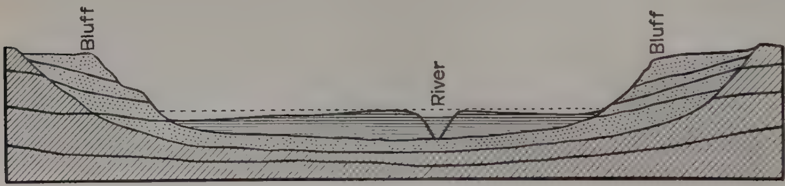
DELTA OF THE MISSISSIPPI

The lightly shaded portion is covered with shallow water.

But where there is a very strong littoral or shore current, it sweeps off the sediment as fast as it enters the sea, and

there is no delta formed. This is the case with the Amazon, the Plata, and with all the American rivers that empty into the Pacific Ocean.

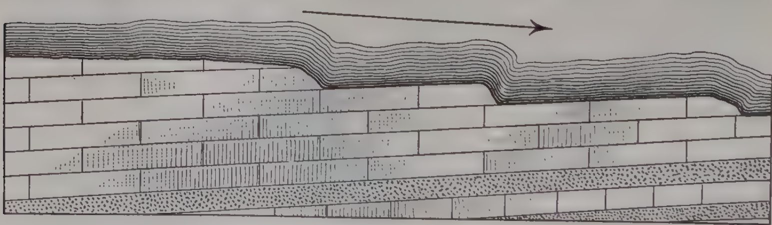
The area of deltas is often very large. That of the Mississippi is about 13,000 square miles. One third of it is still in process of formation, being as yet only a sea marsh.



SECTION OF THE MISSISSIPPI

Sediment is deposited not only upon the beds of rivers, but also upon their banks. This has the effect of raising the banks above the general level of the neighboring country. In some portions of their course both the Mississippi and the Po are above the adjacent fields. The land, therefore, slopes from the river on either side, and one goes *up* to it instead of *down* to it.

Rapids, Cascades, and Waterfalls. — These terms are employed

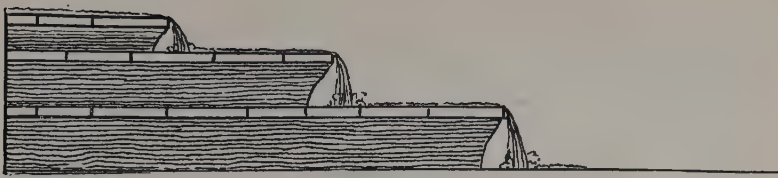


A DIAGRAMMATIC ILLUSTRATION OF RAPIDS

The arrow indicates the direction of stream flow. The outcropping rocks are seen in section.

to denote the more or less violent descent of streams in their passage from a higher to a lower level.

Rapids are formed wherever the stream bed is in the form of a series of steps, as from the successive outcropping of hard strata or where a stream plunging down a declivity is more or less impeded by barriers of hard rock. The rapids above and

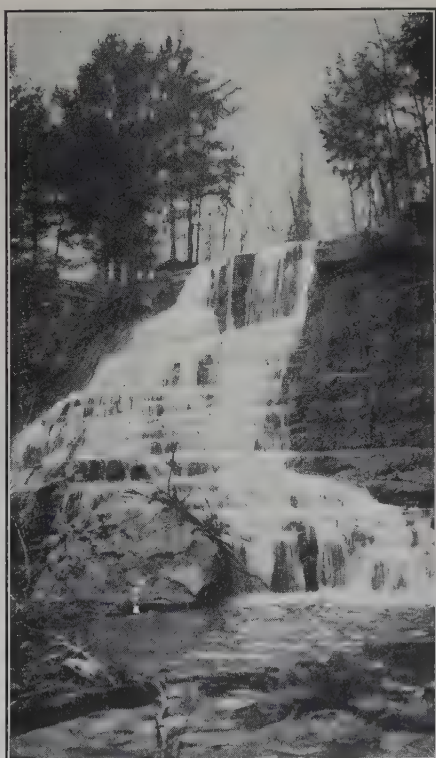


A Diagrammatic Illustration of Cascades

The hard layers form miniature table rocks over which the water falls. The softer, thin bedded rocks below are easily eroded so that each cascade represents a temporary stage in gorge formation.

below Niagara Falls and the rapids of the Saint Lawrence River afford excellent examples of this form of stream descent.

A cascade is a low perpendicular or nearly perpendicular waterfall, usually one of a series by which a stream rather abruptly reaches its lower level. Frequently cascades result from the alternation of hard and soft strata in the stream bed. Falls of the cascade type are especially characteristic of the lake region of central New York. The glens and gorges about the heads of Cayuga and Seneca lakes afford many beautiful examples.



Cascade in the Catskills

The typical waterfall is perpendicular, resulting from the abrupt descent of a stream over a precipice. In regions of stratified rocks the plunge may be over hard rock

THE AMERICAN AND LUNA FALLS, NIAGARA, FROM BELOW

In the foreground is the "Rock of Ages," one of the largest of the fallen limestone fragments.

WHIRLPOOL RAPIDS, NIAGARA RIVER

From a photograph.

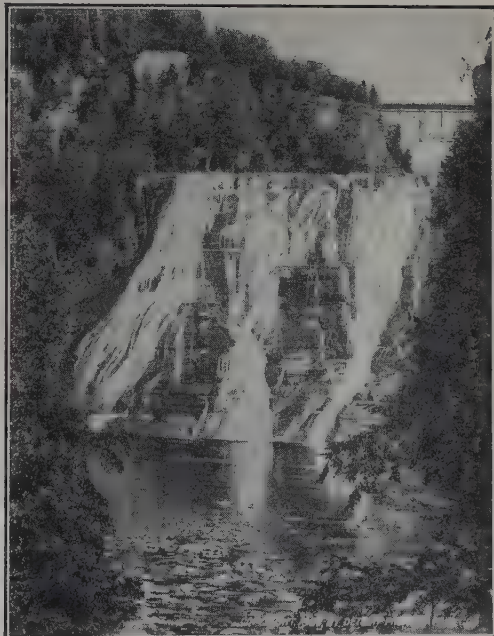
layers (table rock) which are underlain by softer beds. Such is the case at Niagara. Here the harder upper rock is a limestone 80 feet thick. Beneath it there is a softer rock, of about the same

Great Falls of the Yellowstone

From photograph by Haynes.

thickness, made up of very thin layers, known as shale. As the limestone is undermined by the breaking up of the shale by frost and water action great fragments of the table rock drop into the abyss below, and thus the falls gradually retreat up stream. Other forms of perpendicular falls, as in the Yosemite, are caused by streams leaping into a great valley excavated by glacial action.

In regions of igneous rocks waterfalls often result from the unequal resistance of the layers forming the stream bed. A very hard layer, such as basalt, overlying soft and non-resisting layers, will give rise to the typical perpendicular fall as in the case of the Shoshone Falls of the Snake River. In rather unusual instances dikes or walls of hard igneous rocks form the barrier over which streams are precipitated, as exemplified in the Lower or Great Falls of the Yellowstone.



Ithaca Fall, New York
This is a fall of the cascade type.

The Victoria Falls of the Zambezi in Africa are the most remarkable in the world. They are more than a mile wide and over 400 feet in perpendicular height. The river plunges into a narrow ravine running diagonally across the river bed.

Lakes. — The formation of lake basins has been ascribed to many causes, some of which are as follows: (1) great (*diastrophic*) movements of the earth's crust, especially those producing large

downward folds; (2) the obstruction of drainage by the elevation of mountains; (3) subsidence, as in certain regions affected by earthquakes; (4) the damming of valleys by glacial barriers (moraines)

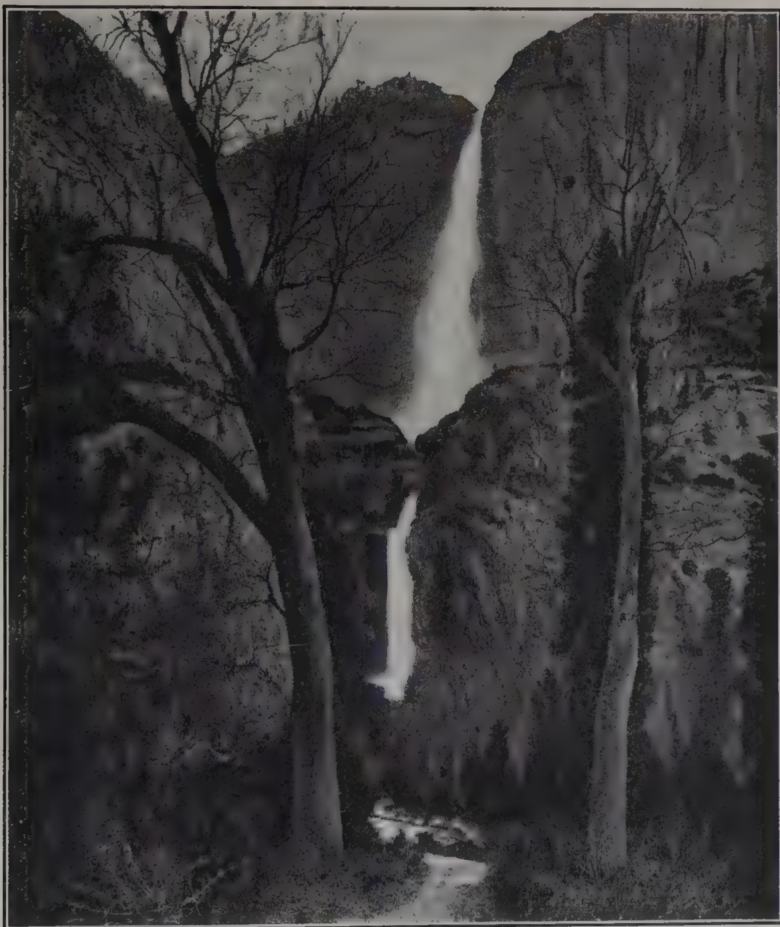
NIAGARA FALLS IN WINTER

The severity of the winter is shown by the great accumulation of ice below the falls.

left upon the retreat of the ice; (5) depressions in glacial drift due to the melting of isolated patches of ice; (6) glacial erosion; (7) volcanic action.

Lake Superior is thought to occupy a great downward fold of the earth's crust, or syncline. Most of the lakes in mountainous regions have resulted from orographic movements. The lakes of the "sunk country" near New Madrid, Mo., sprang into existence as a result of the well-known earthquake of 1811–12. In Switzerland and other mountainous regions small lakes behind glacial barriers are known. The numerous lakelets and ponds in glacial drift, as in Massachusetts, are due to the melting of isolated patches of ice which were left surrounded or buried in débris upon the retreat of the glacier. Some of the lakes of central and western New York, as Cayuga Lake, seem to be due, in part at least, to the formation of rock basins by glacial erosion. Crater Lake, in the Cascade Range of southern Oregon, and similar lakes in other parts of the world, occupy extinct volcanic vents.

Fresh-water and Salt-water Lakes. — In regions where the precipitation or rainfall exceeds the evaporation, lake basins



YOSEMITE FALLS, CALIFORNIA
The height of the upper falls is about 1500 feet.

will be filled with water which, overflowing the rim or breaking through the barrier at some weak point, pushes onward to the

sea, cutting, it may be, a channel through hard rocks; hence the presence, oftentimes, of rapids, waterfalls, and gorges.

In the case of lake basins situated in arid regions, which are characterized by great warmth and dryness, the amount of water

SWISS LAKE SCENERY

Castle of Chillon, Lake Geneva. Dent du Midi in the background.

evaporated is sometimes equal to that which is supplied, and sometimes greater. As fast as the water is poured into these basins by the rivers it is carried away in the form of vapor. Such basins are not filled to overflowing, and consequently have no outlets.

The water of lakes having no outlets is commonly salt. The water of lakes having outlets to the sea is fresh. The reason for this will be readily understood from the following explanation. Rivers carry into lakes many substances in solution, of which one of the most common is chloride of sodium, or common salt. This

is present in ordinary river water, although it cannot be tasted; but if a large quantity of such water were evaporated, a small amount of salt would be left behind. Thus it is clear that if a lake have an outlet, not only is its superfluous water removed, but the salts dissolved in such water are also taken out.

THE DEAD SEA

On the other hand, if a lake have no outlet, then, while the water brought in is removed by evaporation, the salt introduced remains behind. Thus lakes having no outlet may be compared to the evaporating vats or troughs in which, as at many points on the shores of the Mediterranean, sea water is boiled, or evaporated by solar heat, in the manufacture of salt. The water passes off, the salt remains. Hence, year after year, salt lakes become salter.

Conspicuous examples of salt lakes are the Great Salt Lake and the Dead Sea. Both of these are heavily charged with saline ingredients. The water

of the Dead Sea is about one fifth heavier than that of the ocean, and sustains the human body, so that it cannot sink in it. From its great salinity the Dead Sea is often called the Sea of Salt. But the Jordan, which supplies it, is of course fresh.

The Dead Sea is situated in a depression remarkable for its intense heat, and the region in which the Great Salt Lake lies is very remarkable for the dryness of its atmosphere. In the case of both these lakes, therefore, evaporation proceeds at an enormous rate.

CAYUGA LAKE FROM CORNELL HEIGHTS, ITHACA, N.Y.

Inland Seas. — Some inland bodies of salt water, however, have evidently been at one time parts of the ocean. These are properly designated inland seas. The most remarkable of them are the Caspian and Aral.

When the Arctic Ocean extended, as geologists believe it did, southward as far as the mountains of Persia, these two seas and many neighboring bodies of salt water were included within its limits.

Seals abound in the Caspian, and sturgeons, herrings, and other sea fish in both the lakes.

Like other salt lakes, these inland seas have no outlet. The

Volga, the largest river in Europe, and the Ural pour volumes of water into the Caspian, yet its level does not rise. Lake Aral receives the Amu and Syr rivers, yet its level seems actually to be lower than formerly.

Many small salt lakes entirely evaporate during the summer, and leave their beds covered with saline incrustations. From the

CRATER LAKE, OREGON

This unique body of fresh water is situated in the Cascade Range of southwestern Oregon. Occupying a depression, known as a caldera, formed by the subsidence or caving in of a great volcanic summit — Mount Mazama — its surface is 6,239 feet above sea level. Its shape is somewhat elliptical, its diameters being 6¼ and 4¼ miles respectively. Its depth approximates 2,000 feet. A single island, in the form of a cinder cone, rises above its waters. There is no outlet, the steep walls of the caldera rimming the lake on all sides.

dry bed of Lake Elton, in the Caspian region, 100,000 tons of salt are annually gathered.

Desiccated or Evaporated Lakes. — Salt and alkaline lakes are usually the remnants of larger bodies of water which have greatly shrunken or almost disappeared on account of the aridity brought about by climatic changes. The former existence of such lakes is shown by easily recognized basins and shore lines, as in the case of Lake Bonneville, in Utah, and Lake La-

hontan, in Nevada. Great Salt Lake is a survival of the former, while Carson, Pyramid, Winnemucca, Humboldt, and other lakes fill depressions in the basin of the latter.

A CALDERA, CANARY ISLANDS

Calderas or "caldrons" are large craterlike depressions which often measure several miles in diameter. In some instances they seem to have resulted from violent eruptions, during which volcanic summits have been blown completely away; in others, they have evidently been formed by the subsidence or caving in of volcanic cones. See Crater Lake.

The waters of Lake Bonneville, which were fresh, flowed into Snake River. Lake Lahontan had no outlet and its waters were probably never fresh. As these lakes diminished in volume, the water became more and more concentrated, until the mineral matter held in solution was precipitated. The first substance deposited was carbonate of lime in the form of *tufa*. This is found along the ancient shores of Lake Bonneville and in much greater abundance along those of Lake Lahontan. Great Salt Lake is rich in salt (sodium chloride); the Nevada lakes are not. As an explanation of this difference, it as been suggested that Lake Lahontan had probably been evaporated to dry-

ness, truly *desiccated*, and that later, under slightly changed climatic conditions, which permitted the formation of smaller bodies of water, the salt beds that must have existed were buried under clay deposits, and therefore do not affect the waters of the present lakes.

Offices of Lakes. — Lakes act as reservoirs and thus oftentimes prevent the flooding of rivers. The waters of the upper

Upper Lake of Killarney, Ireland

The Lakes of Killarney are famous for their beauty. They lie in the southwestern part of Ireland about 35 miles northwest from Cork.

tributaries of a stream, swollen by recent and heavy rains or by the rapid melting of snow, upon reaching a lake spread out and are held back, in consequence of which the flow at the outlet is not greatly increased. As the inundations of the lower Mississippi are mainly due to the floods of its tributaries, there being no intervening lakes to hold back the surplus waters, it has been proposed to regulate its flows by the erection of impounding reservoirs on its headwaters.

Furthermore, lakes act as settling basins. The water flowing

into a lake may be laden with sediment, even the finest glacial silt, but the water flowing from it will be clear, containing no matter held mechanically in suspension. Hence it follows that a lake may become completely filled with detritus brought in by flowing streams. When this stage has been reached, the lake gives place to a plain through which the supplying stream meanders. This is illustrated in a small way by the accumulations deposited in the reservoir behind an old dam.

Geographical Distribution of Lakes. — In North America are found the vast bodies of fresh water which are called the "Great Lakes."

Lake Superior, a member of this group, is the largest body of fresh water in the world. Its area is over 30,000 square miles. The surface of this great inland sea has an altitude of 602 feet, but its bottom extends below the sea level 406 feet.

The northern part of the Great Central Plain of the continent abounds in lakes of greater or less magnitude. In the basin between the Rocky Mountains and the Sierra Nevada there is a region of saline lakes.

In Europe, the great lake region lies in northern Russia and Scandinavia. Ladoga and Onega, Wener and Wetter, are the largest lakes of the grand division. Those of the Alps, Como, Maggiore, Geneva, and others are comparatively small, but famed for their beauty.

Asia is noted for the size and number of its salt lakes. The Caspian Sea, Lake Aral, and the Dead Sea are examples.

Of fresh-water lakes Asia has few. Lake Baikal, however, 400 miles in length, may be compared with our own Lake Superior.

Africa rivals North America in the magnitude of her great lakes. Victoria and Albert Nyanza, Tanganyika and Nyassa, are the largest.

South America has one lake of importance, Titicaca. Australia is noted for its salt lakes. Eyre, Torrens and Gairdner each exceed 100 miles in length.

XV. DRAINAGE

Advantages of Drainage. — The drainage of the land depends primarily upon its relief. Those countries best adapted for human habitation are well drained. Crops do not flourish on cold, damp soils, nor can human health and strength be maintained where the ground is always wet. As is well known, the vicinity of swamps is especially unhealthful.

For this reason a very large area of the sunny peninsula of Italy, called the Campagna, once densely populated, is almost uninhabited. From the days of ancient Rome it has remained, owing to the level nature of the land, and the consequent absence of any stream into which the waters might be directed, a vast swamp and a breeding ground of pestilence. It is now being reclaimed.

How Drainage is Effected. — Rivers are the channels through which the water carried from the sea in the form of vapor and rained upon the land finds its way back to the sea. Every running stream may therefore be regarded as a kind of rain gauge, which measures, in a general way, the quantity of rain that falls upon the valley which it drains.

The region drained by a river system is called the *river basin.* The basins of large streams are hundreds of thousands of square miles in area. That of the Mississippi contains nearly 1,250,000 square miles.

The limits of a river basin are defined by what are termed *watersheds;* that is, water divides, *shed* being from a German word meaning to divide. A watershed is a line of elevation, sometimes lofty and sometimes low, which, like the ridge of a roof, divides the rain as it falls, and causes one portion to descend one slope of a country or continent, and the other portion another.

If on a map of North America you trace a pencil line round the sources of all the rivers that pour into the Mississippi from the Appalachian slope on the one side, and from the Rocky Mountain slope on the other, you will have marked out the watersheds which define the eastern and western limits of the Mississippi basin.

The mountains and slopes of every country determine in a large measure the number of its water courses, their length and direction, and the velocity of their currents; in a word, their capacity for carrying off superfluous rain water.

Inundations. — The inundations or floods which occasionally submerge large areas of land, and are so destructive to life and property, occur where the quantity of water to be removed exceeds the capacity of the draining rivers. Many rivers, as the Nile, the Orinoco, and the Mississippi, are subject to periodical overflow. So extensive are the inundations of the Po that the Italian engineers have actually proposed a scheme for cutting an artificial channel to be used in case of emergency.

FLOODED LANDS AT SINGAC, NEW JERSEY, ON THE PASSAIC RIVER

From United States Geological Survey.

The chief causes of floods are to be found in seasonal changes. They affect the rainfall and cause the melting of snow both on high mountains and in river basins. The sudden disappearance of winter snow is always accompanied by swollen streams.

The melting of snow in Pennsylvania, Ohio, Indiana, and Illinois, together with copious spring rains, are annually followed by a marked rise in the Ohio

and its tributaries, and when the snows of the Rocky Mountains begin to melt, the western tributaries of the Mississippi are flooded and that stream experiences the "June rise."

North America. — The bounding waters of North America are the Arctic Ocean, the Pacific Ocean, and the Atlantic, including the Gulf of Mexico. These receive the drainage of the grand division.

The great watershed is the Rocky Mountain system. It acts like the ridge of a roof, shedding the water to the east and to the west. All the region lying westward of it is drained into the Pacific and into Bering Sea by the Colorado, the Columbia, the Fraser, the Yukon, and other rivers of less importance.

East of the Rocky Mountains the grand division is divided into four slopes: a northern, inclining toward the Arctic Ocean; a northeastern, toward Hudson Bay; an eastern, toward the Atlantic; and a southern, toward the Gulf of Mexico.

The largest river draining to the Arctic is the Mackenzie. The Saskatchewan-Nelson is the chief system draining to Hudson Bay. To the south lies the great basin of the Mississippi, the drainage of which is poured into the Gulf. This basin embraces the enormous area which lies between the Rocky Mountains and the Appalachians.

The amount of water carried by the Mississippi from this region into the Gulf of Mexico every second is 675,000 cubic feet, enough to cover about 18 acres of ground to the depth of a foot. We can see from this how soon the Mississippi basin would become a desolate swamp, if it were a dead level untrenched by its mighty system of rivers.

The eastern slope of the grand division, including the terraced plateau occupied by the Great Lakes, is drained by the Saint Lawrence and by a series of rivers, large and small, which flow from the Appalachians to the Atlantic.

South America. — The drainage of South America, like that of North America, is mainly effected by three river systems. The

crest of the Andes is the great watershed. It lies along the western edge of the grand division. Hence the drainage has in general an easterly flow.

The eastern slope embraces nearly the whole of the grand division. It is divided into three great river basins, those of the Orinoco, the Plata, and the Amazon. The last contains the greatest river system on the globe.

The Amazon discharges six times as much water as the Mississippi. In respect to volume it is the largest river in the world. It rises in the beautiful little lake of Lauricocha, high up among the Andes. Descending by falls and rapids, it reaches the region of the silvas, and then becomes a stream navigable for large steamers from the foot of the mountains to the sea, a distance of about 2200 miles.

So great is the force of its current that its fresh waters are carried a distance of about 200 miles from the land. An ocean current passing near its mouth sweeps away sediment as fast as the river brings it down. Thus the river's own current and the ocean current prevent the formation of a bar.

The western slope of South America is steep and narrow. There is no room for long rivers, and no water for large rivers. The Pacific receives only a few small mountain torrents, fed by the melting snows of the Andes.

Europe. — From a point in the Ural Mountains at about latitude 61° north, to the Valdai Hills, thence in a southwestward direction through central Europe down to the southern shores of Spain, an irregular line may be traced which will separate Europe into two great slopes. The one inclines to the northwest, the other to the southeast.

All the rivers have one or the other of these two general directions; and the grand division is drained into the Mediterranean, the Adriatic, the Black, and Caspian seas on the one side; or into the Atlantic and Arctic oceans, and the North, Baltic, and White seas on the other.

The region of the Alps is drained by four streams, the beautiful Rhine of the Germans, the Rhone, the Danube, and the Po; the drainage of the low plains is accomplished by a number of rivers, among which the Volga, the Don, the Dnieper, and the Dniester are conspicuous.

Asia. — The grand division of Asia, like that of Europe, may be regarded as consisting of two great slopes, one having a general incline toward the north, the other toward the south and east.

Beginning on the western shore of Asia Minor, a line may be drawn to Mount Ararat, thence along the crests of the Elburz and Hindu Kush Mountains, thence northeastwardly to the Sea

View on the River Nile
Water carriers filling their "skins."

of Okhotsk, which will represent the great watershed of the grand division.

Southeast of this line the Euphrates and Tigris, the Indus, Ganges, the Yangtse, the Hoang, and Amur carry the drainage to the southward and eastward into the seas and bays of the Pacific and Indian oceans.

On the northern side of the line nearly every important river flows in a northerly direction into the Arctic Ocean.

Africa. — The drainage of Africa is accomplished in the main by the four great river systems of the Nile, the Niger, the

Kongo, and the Zambezi. Much of the surplus water of the grand division, however, is removed by evaporation.

The most interesting feature in the drainage system of Africa is the river Nile. But for it Egypt would be as barren as the Great Desert of Sahara. The river is formed by the junction of two streams called the White and the Blue Nile. The former issues from the Equatorial Lakes. The latter rises among the hills and the table-lands of Abyssinia.

During June, July, and August the rains pour down in torrents upon the regions drained by these streams. Each is flooded. Uniting at Khartum, the descending torrents reach Cairo by the middle of June, and during the latter part of summer and in the autumn the land of Egypt is under water.

As the flood subsides, a layer of fertilizing sediment is deposited upon the soil. Most of it has been washed down from the Abyssinian hills by the Blue Nile, which takes its name from the color which the sediment imparts to its waters.

Australia is scantily supplied with rivers. The Murray and its tributaries are the only water courses of importance. During times of drought the latter cease to flow and the main stream is greatly shrunken.

XVI. THE SEA AND THE OCEANS

Extent of the Sea. — Less than three fourths of the earth's surface is covered by water. This surface comprises, in round numbers, an area of 197,000,000 square miles, of which about 55,000,000 are land and 142,000,000 water. All of the land, except 13,000,000 square miles, is on the north side of the equator. The northern hemisphere therefore contains approximately three fourths of all the known land, and two fifths only of the water surface, of the world.

The extent of water that is visible to the eye at one time is not great. If we stand on the shore and look seaward, our view is closed in by a line in which sea and sky appear to meet. To this line we give the name *horizon;* that is, bounding line. Its distance from us depends on our elevation. If we occupy a position which is elevated six feet above the sea level, our horizon will be three miles off. If we ascend a bluff or lighthouse, and so gain a point about 100 feet high, our horizon will be 12 miles distant.

Saltness of the Sea. — Various solids are found dissolved in sea water. Of these the most abundant is common salt. Others are certain compounds of lime, magnesium, potassium, and iodine. The solid matter may be estimated on an average as about one thirtieth part of the whole by weight.

Though there is little variation from the average, it seems to be well ascertained that there are areas, as within the region of the North Atlantic trade winds, for example, where the proportion of saline matter is greater than elsewhere. This may be expected, since evaporation [1] is there at its maximum. On the other hand, the proportion of salts is reduced where great rivers empty into the sea or where great bodies of ice melt.

[1] Evaporate a small portion of sea water until it is very much concentrated. Then warm a drop of this concentrated fluid on a piece of glass, and put it instantly under a microscope. You will see the saline substances, which have given the sea water its peculiar taste, crystallizing in regular shapes, as the water gradually dries from the glass.

Saltness of partly Inclosed Bodies of Water.—Theoretically, owing to excessive evaporation, the waters of the Mediterranean Sea ought to contain a greater proportion of saline matter than the adjacent Atlantic, and such is said to be the case off the coast of Tripoli, where they are subject to rapid evaporation by the hot winds from the Libyan desert.

In the Red Sea, too, there is a concentration of saline matter. No streams of any consequence flow into it, and, almost completely landlocked, it is subject to excessive evaporation; so that it exhibits a degree of saltiness found only in some salt lakes.

Phosphorescent Sea

In higher latitudes, where the evaporation is not so great, and where there is a large inflow of terrestrial water, landlocked seas are less salt than the adjacent ocean. Some parts of the Baltic, for instance, are almost fresh.

Color of the Sea.—The sea is green or blue; it is sometimes colored here and there by reddish, or whitish, yellowish, or crimson patches, according to the tints imparted by the color of the bottom, by the shadow of the clouds, by the ingredients of its waters, or by its myriads of organisms. In certain parts of the Indian Ocean the waters, as seen from a distance, are black.

In the Mediterranean, in the Gulf Stream, and between the tropics generally, the sea waters are dark blue; along the shores and near the mouths of great rivers and in coral seas they are green.

Thus the sea assumes here and there various shades of color; yet its waters, when viewed by the tumblerful, are as clear as the purest crystal.

Phosphorescence.—In most parts of the sea the water is phosphorescent. The phosphorescence is caused by certain minute living bodies which, like glowworms and fireflies on the land, have the power of emitting light, some in flashes, and some in a steady glow. These little creatures, invisible to the naked eye, are as multitudinous as the sands on the shore.

IN ARCTIC ICE

Breaking out of Etah. Peary expedition. From Bulletin of the Philadelphia Geographical Society.

In tropical seas and in certain waters they tip the waves with flame, and cover the sea after dark with sheets of light. As the ship plows these waters, she leaves a bright streak far behind in her wake.

Though we cannot see the dolphin and other fish, as they sport in the depths of these phosphorescent seas, yet, by the streaks they leave behind,

we can often track them through the water, as we do rockets through the air. As they chase each other in the mazes of their sport, these threads of light are, to those who are fortunate enough to see them, among the most pleasing wonders of the deep. They are particularly beautiful in the harbor of Callao.

The Temperature of the Sea is in general highest near the surface. In the equatorial waters the average surface temperature is about 80° F., sometimes rising in the Indian Ocean to 90°, and in the Red Sea to 94°. Toward the bottom the temperature is depressed. Indeed, near the bottom all over the globe deep sea water seems to be about as cold as that of the polar seas.

During the Arctic winter the sea is frozen to the depth of several feet, forming floe ice, through which, by the action of the tides, currents, and winds, temporary channels or leads are opened. Taking advantage of these water ways, the explorer or navigator urges his ship onward. Oftentimes, however, the channels are closed with prodigious force and his vessel nipped if not crushed. As a result of this ice movement barriers of broken or pack ice are formed which may reach the height of 100 feet.

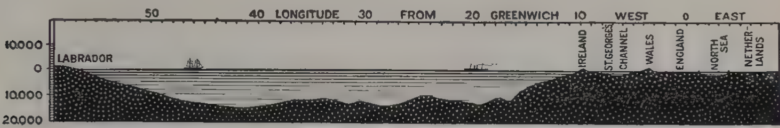
The Oceans. — The sea is one immense body of water encircling the globe. It is, however, divided by the intervening land masses, or continents, into smaller bodies, called *oceans*. Of these the Pacific is the largest. It contains more than half the water of the sea. Next in size, but only about half as large as the Pacific, is the Atlantic. The Indian is the third in area. The Arctic is properly only an extension of the Atlantic, while the Antarctic hardly deserves to be regarded as distinct from the main body of the sea.

The form of each ocean basin depends upon the shape of the inclosing continents. The Pacific approaches the oval; the Atlantic has been compared to a long trough; the Indian is triangular; while the polar oceans are very irregular.

Of all the oceans the Atlantic is the most marked by indentations of its shores. The Asiatic edges of the Pacific and Indian oceans are also well supplied with bays and border seas.

Depth of the Oceans. — Two questions connected with the

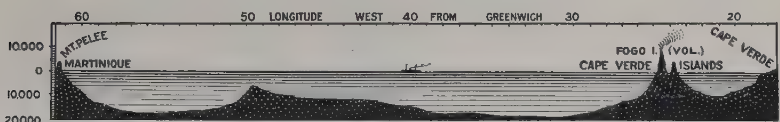
subject of ocean basins have been made matter of accurate investigation — their depth and the configuration of their bottom.



VERTICAL SECTION OF THE ATLANTIC OCEAN AT 52° NORTH LATITUDE

The average depth of the Atlantic is about 12,000 feet. It seldom exceeds 18,000 feet, or $3\frac{1}{2}$ miles. The deepest sounding has been made 70 miles north of Porto Rico. It was 27,366 feet, or rather more than five miles.

The Pacific has a somewhat greater average depth than the Atlantic. Like the Atlantic, it has deep abysses. Soundings of 27,930 feet have been made in a large depression, known as



VERTICAL SECTION OF THE ATLANTIC OCEAN AT 14° 48′ NORTH LATITUDE

Tuscarora deep, east of northern Japan and the Kuril Islands, and one of 30,930 in Lat. 30° 27′ 7″ S., Long. 176° 39′ W. The greatest depth known, however, 31,614 feet, is near the island of Guam, a southern member of the Ladrone group.

The Bottom of the Ocean is, like the land, diversified with hill and dale. Vast plateaus, banks, and shoals spread themselves out; and islands rise from the ocean depths far more abruptly than mountains do from the lowlands.

Haiti and many other islands of the sea rise from the bottom to the surface almost perpendicularly. The Silla de Caracas, on the other hand, which is the steepest mountain in the world, rises at an angle of 53°.

The bed of the Atlantic has been more thoroughly examined than any other. It seems to consist of two nearly parallel

valleys extending north and south and separated by a lofty dividing ridge. The islands which are scattered along its length are the summits of this ridge. That portion of the Atlantic bed to which the name of *Telegraphic Plateau* has long been given is of special interest. This plateau stretches entirely across from Newfoundland to Ireland, at an average depth of somewhat less than two miles.

If we imagine ourselves walking across it from Newfoundland to Ireland, we shall first descend by an easy slope to the Grand Banks. Here the depth is about 1000 feet. Leaving the Grand Banks, we shall pass quite rapidly to the depth of about 13,800 feet. From this point there is not much variation in the depth for about halfway across the ocean. When, however, we have performed half our journey, we shall ascend again, first rapidly and then gently, until we reach the neighborhood of the British Isles. For a distance of about 230 miles westward of Ireland the upward slope is very gradual until we gain the dry land.

NOTE.—The practical value of the information derived from the Atlantic deep-sea soundings was early appreciated by Maury. Almost as soon as the results of the soundings were made known to him, he saw that the laying of a telegraphic cable was a practicable project. He was the first to suggest and urge the carrying out of this scheme, the accomplishment of which has been one of the grandest achievements of modern science. To Maury belongs the glory of having pointed out a highway under the waters, whereby the ends of the world have been brought into instantaneous communication.

Marine Deposits may be classed as *marginal* and *abyssal.*

To the first group belong the silt and sand brought down by rivers, the waste of the continental borders, and the ooze resulting from the wear of rocks by glacial action. To these materials must also be added fragments of the solid parts of marine animals, especially the shells of mollusks. The average width of marginal deposits is about 150 miles, although in some regions, as off the mouth of the Amazon, they may reach 350 or 400 miles. Deposits similar to those here mentioned are found in inland seas.

Abyssal deposits are spread over the bottom of the deep sea. While largely of volcanic origin, as shown by microscopic examination, they exist also in the form of ooze of organic origin. Deposits of the sea, like those of the land, are chemically modi-

CHART SHOWING THE DISTRIBUTION OF MARINE DEPOSITS. After Daubree

Marginal Deposits, white; Red Clay, horizontal lines; Globigerina Ooze, vertical lines; Radiolarian Ooze, vvv; Diatom Ooze, broken horizontal lines; Coral Sand and Mud :::.

fied and take on characteristic forms. Of the abyssal deposits *red clay* is the most widely distributed. Its volcanic origin is shown by the presence of pumice and other igneous matter. Associated with the red clay are found the calcareous and silicious coverings of minute marine organisms. Within certain areas they occur in such abundance as to form a distinct ooze; thus the accumulation of certain foraminifer shells, belonging to the *Globigerina*, may give rise to *globigerina ooze*, a limy or calcareous mass, which is represented in the earth's crust by chalk. Again, the great abundance of *Radiolaria* shells may give rise to a *silicious ooze*. Near the south pole there is a rather large area covered with a silicious ooze which has resulted from the accumulation of the hard parts, or coverings, of low forms of plants known as *Diatoms*. The distribution of the various marine deposits, including the coral sands and muds, is shown on the preceding page.

XVII. WAVES, TIDES, AND CURRENTS

Waves. — "The troubled sea that cannot rest" has ever been the emblem of unending movement. Waves, tides, and currents incessantly disturb it.

Waves are caused by the wind which strikes upon the surface of the sea, and thus produces an alternate downward and

BREAKERS APPROACHING THE SHORE

Coronado Beach, San Diego, California. Point Loma on the right.

upward movement of its waters. A mass of water moved in this way is called a *wave*. The elevated portion of the water is called the *crest;* the distance from one crest to another is the *breadth;* the depression between two crests is called the *trough*.

The rolling in of waves upon the beach produces the impression that the entire body of water is moving toward the land. As we shall see, however, when we come to consider the subject of tides, it may actually be receding. We must, therefore, distinguish between the motion of the waves and the motion of the water.

If we produce a ripple upon the surface of water in a basin, bath, or pond, the ripple will travel from edge to edge of the water, and communicate an undulating or wave movement to each portion of the surface. But the water itself has no progressive movement.

BREAKERS ON THE SHORE

Coronado Beach, California. Point Loma on the right. From photograph by H. R. Fitch.

The action of a breeze upon a field of wheat, or tall grass, illustrates the matter very forcibly. The wind passes over the field, and each stalk and blade bends alternately down and up, thus forming depressions and wave crests. Yet there is no onward movement of the stalks.

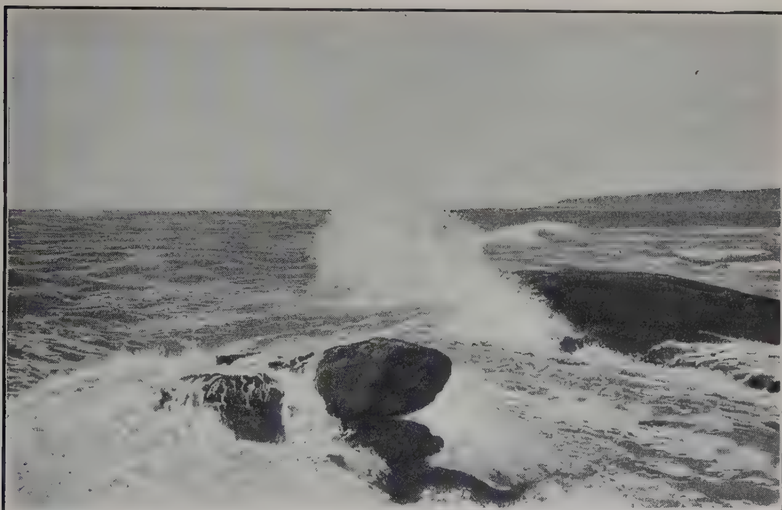
Those portions of the water, however, which actually reach the shore, do possess an onward movement. Instead of being driven against an adjoining mass of water, they encounter the solid bottom. Thus the lower part of their mass is retarded, while the upper part moves onward, curls, and dashes as a *breaker* upon the beach.

The Height of Waves depends mainly upon the force of the wind and the depth of the water. In general they are not more

than 8 or 10 feet high. The highest known are those off the Cape of Good Hope, where they are said to attain the height of more than 40 feet.

The bell of a lighthouse on one of the Scilly Islands, east of Lands End, was wrenched off by a breaker, at the height of 100 feet.

The Velocity of Wave Movements depends (1) on the velocity and force of the wind; and (2) upon the depth of the water and its freedom from obstructions. In the open sea the advance of



WAVE ACTION ON PARTLY SUBMERGED ROCKS, SAN DIEGO COUNTY, CALIFORNIA
From photograph by H. R. Fitch.

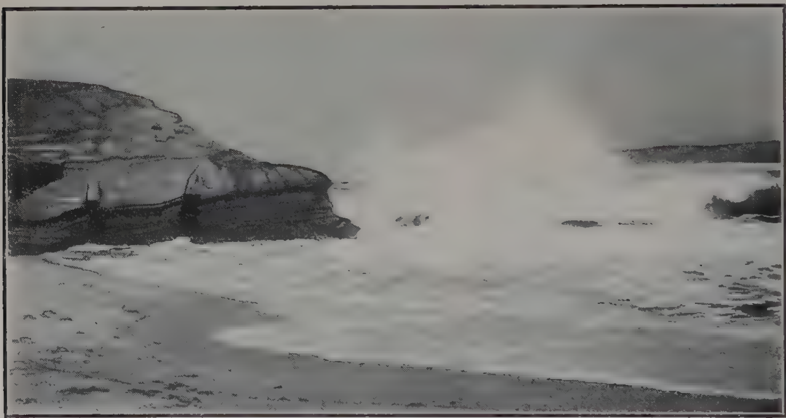
a wave movement is more rapid than in one obstructed with islands. The rate of ordinary wave travel is from 15 to upwards of 50 miles an hour.

The wave movements of the ocean are incessant. Even where a perfect calm prevails, there is a ceaseless movement of the water, which, like a great pulse, keeps the surface constantly rising and falling. This heaving is commonly known as the ground swell of the ocean.

Waves affect the surface chiefly. The highest waves in a storm have no appreciable effect in water more than a quarter

of a mile in depth. A wave 40 feet high and a quarter of a mile in breadth would not, in all probability, disturb the smallest grain of sand lying on the sea bed at a depth of 200 fathoms.

Force and Work of the Waves. — The heaviest billows beat against the shore with enormous force. They undermine and level cliffs, they dash great rocks to pieces and grind the fragments into gravel and sand which, distributed along the shore, form the beach. Sand is the common beach material, though in



WAVE ACTION ON A ROCKY HEADLAND, LA JOLLA, SAN DIEGO COUNTY, CALIFORNIA

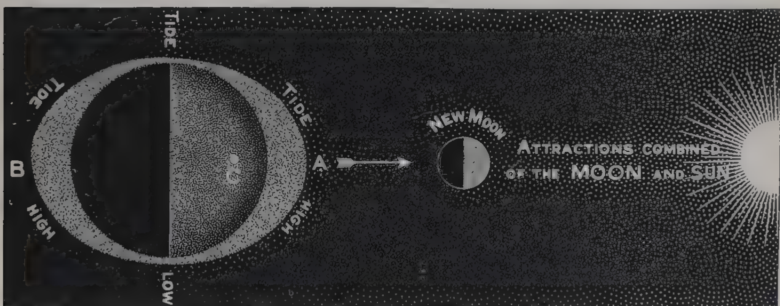
Note also the sandy beach in the foreground and the high surf in the center of the picture where the waves strike the submerged rocks. From photograph by H. R. Fitch.

times of storm bowlders may be thrown up by the waves or broken down from cliffs and headlands. The shore has often been likened to a mill where the grinding of rocks into sand is a ceaseless operation.

Under the influence of waves beaches may be extended into spits or points, and sand thrown up as barrier islands. The latter are especially well illustrated by the long, narrow sand barriers of the Gulf coast of Texas.

Under certain conditions waves also act as transporting agents. The presence of silicious sand on the lower coast of Florida, where the rocks are coralline limestone, is thus accounted for.

The Tides are great wavelike movements. They differ from wind waves, (1) in their extent; (2) in their regularity; (3) in their cause. In a general way it may be said that two large waves, each having its crest and its depression, together encircle the globe from north to south. These two ceaselessly chase each other over the broad expanse of the sea, occasioning two elevations and two depressions of its waters in the course of about 25 hours.[1] From the fact that these elevations and depressions occur with regularity about one hour later each day, and thus rudely mark the time, they are called *tides*, from the Anglo-Saxon *tîd*, time.



SPRING TIDES

The elevation or rising of the water is called *high* or *flood tide;* its depression or falling, *low* or *ebb tide.* These occur alternately every six hours.

Cause of Tides. — The tides are mainly due to the influence of the moon. The sun also has a tide-producing power, but it is insignificant compared to that of the moon, owing to the fact that the sun is 400 times farther off.

The moon is comparatively near the earth. Let us see then how, in consequence of this, she affects its waters. The earth and moon may be regarded as two bodies revolving about a common center of gravity *c*, which, owing to the greater mass of the earth, as compared with that of the moon, lies 1000 miles

[1] The exact time is 24 hours 52 minutes, or what is known as a lunar day, the time between the crossing of the meridian of a place by the moon and her appearance on the same meridian again.

within its circumference. The two bodies are exactly balanced at their centers, but the surface of the earth at B is 7000 miles from the common point about which the earth and moon revolve, in consequence of which there is developed a throwing off or centrifugal force, known to every schoolboy who has used a sling or whirled a bucket of water over his head, which partly

HIGH TIDE AT OSTEND, BELGIUM

Ostend is noted as a pleasure resort, its beach affording excellent opportunities for bathing. In front of the buildings is a protecting wall. The hill-like elevations at the right are dunes.

overcomes the force of gravity and permits the outward bulging of the water in the form of a tidal wave. At A, however, in addition to the slight centrifugal tendency resulting from the movement about C, the tidal wave is generated by the direct attraction or pull of the moon.

Halfway between the tidal wave crests or high tides, there are depressions, as represented in the illustration. These occur where the water is drawn away to form the high tides.

They create the low tides. Like the high tides, they take place twice in a lunar day, at intervals of a little more than 12 hours.

Evidence that the moon chiefly is concerned in causing the tides is found in the fact that high tide at any place occurs nearly at the time when the moon is over the meridian of that place.

LOW TIDE AT OSTEND, BELGIUM

The receding waters have left a broad beach, now thronged with visitors. In the background at the left, standing high above the water, is seen the landing pier.

A marked phenomenon of the tides is that the intensity of the movement varies. Three days after full and new moon the flow or rise of the water is far greater than usual. This is explained by the fact that when the moon is new, as in the illustration on page 183, and when she is full, the sun and moon combine their tide-producing forces, forming what are known as the *spring tides*. During these the flow is at its maximum. When, on the other hand, the moon is entering her second and her fourth

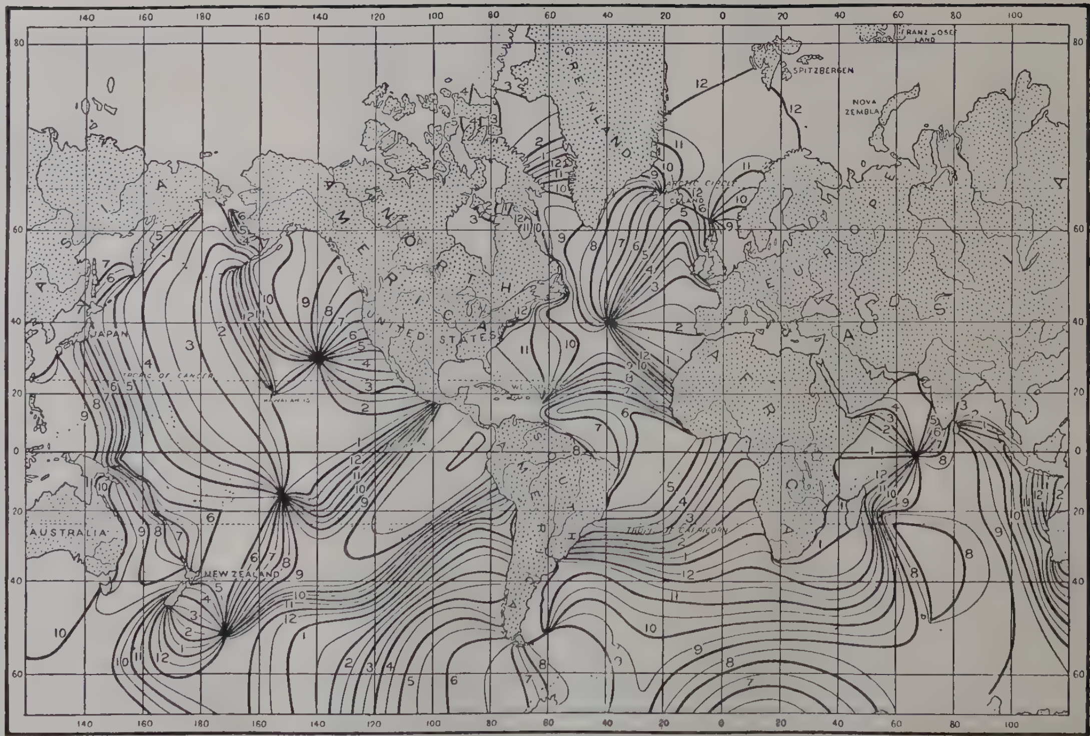


CHART OF COTIDAL LINES—U. S. Coast and Geodetic Survey

quarters, the two forces do not act in harmony, and as a consequence the *neap tides* result, in which the height is much less than in the spring tides.

Movement of the Tidal Wave. — Were it not for the interference of the continents and the variations in the depth of the sea, a tidal wave might be expected to follow the apparent course of the moon about the earth. Such a wave would then move from east to west with its crest extending in a north-and-south direction. The sea, however, is divided by the land into great oceanic basins of varying depths. By the continents the wave is deflected from its course, and according to the depth of the water its velocity is increased or diminished, being accelerated in the deeper water and retarded in the shallower. The movement of the tidal wave is shown on a chart by means of cotidal lines which connect all places having high water at the same time. They therefore represent the crest of the tidal wave.

Speed of Tidal Wave. — Since the tides follow the moon, they have to travel round the earth from east to west in the same time that she appears to revolve round it; namely, 24 hours and 52 minutes. The tidal wave, therefore, in equatorial seas, would, if it were unobstructed, and could pursue a direct course, travel at the rate of 1000 miles an hour.

It must be borne in mind, however, that the water in midocean has only an imperceptible progressive motion; it is the undulation, not the water, that travels at this high rate of speed.

The waving grain, as it bends to the breeze, causes an undulation that travels across the field faster than you can run; but the stalks are rooted; they only sway backward and forward to the breeze. So it is with the deep sea and its swell.

When, however, the tidal wave comes near the shores, where the water is shallow and confined, a change occurs. The undulation is retarded, but the motion of the water is vastly increased, and it sweeps as a current along the continental shores and up the bays and rivers. The current gains in speed as the tidal wave loses.

ATLANTIC COAST TIDES
Mean height, in feet.

The current often attains unusual speed in passing headlands, and then the term *race* is commonly applied to it. Such an accelerated current moves from six to eleven miles an hour.

Height of Tides. — In the middle of the Pacific Ocean the rise of the tide is sometimes less than a foot; in the Atlantic, near Saint Helena, about three feet. On the other hand, between the converging shores of narrow seas and bays the water is sometimes heaped up to the height of from 25 to 40, and, in the Bay of Fundy, from 50 to 60 feet.

The Mediterranean and the Red seas, however, with their narrow entrances, almost cut off the tidal wave, so that in both the ebb and flow are very slight. The greatest rise in the Mediterranean is about 1.2 feet. This seldom occurs.

In the Caribbean Sea and Gulf of Mexico, likewise, the tides are rarely three feet high, owing probably to the fact that these sheets of water are protected from the tidal wave by the West Indies.

Very great differences exist between the tides at various points of the same coast. On the shores of Florida the rise is not more than about three feet. It increases as we go northward, until we reach the Bay of Fundy, where it attains its maximum.

At some points on the shores of Great Britain there are tides of great height and strength, while at others

close by, the rise and fall are barely perceptible. The rise and fall at Liverpool are 28 feet; in the Bristol Channel, 40 feet; at Wicklow, on the opposite Irish coast, only 2 or 3.

To account for these differences various causes may be suggested: the form of the bottom, the projection of headlands, the narrowing of channels along which the tidal current is forced, and the position of those channels with reference to the direction of the tidal wave.

A glance at the map shows, for example, that were the tidal wave propagated from the northeast instead of the southwest, the Bay of Fundy would cease to have remarkably high tides.

The peculiarities of a shore are sometimes such as to cause a complete sundering or division of the tidal waters. Two currents are thus formed. In some cases these meet again after their division and give rise to a *whirlpool.* Charybdis in the Straits of Messina, and the Maelstrom among the Lofoden Isles, are illustrations of this phenomenon.

Tides of Rivers; Bores. — The tides of some rivers present interesting peculiarities.

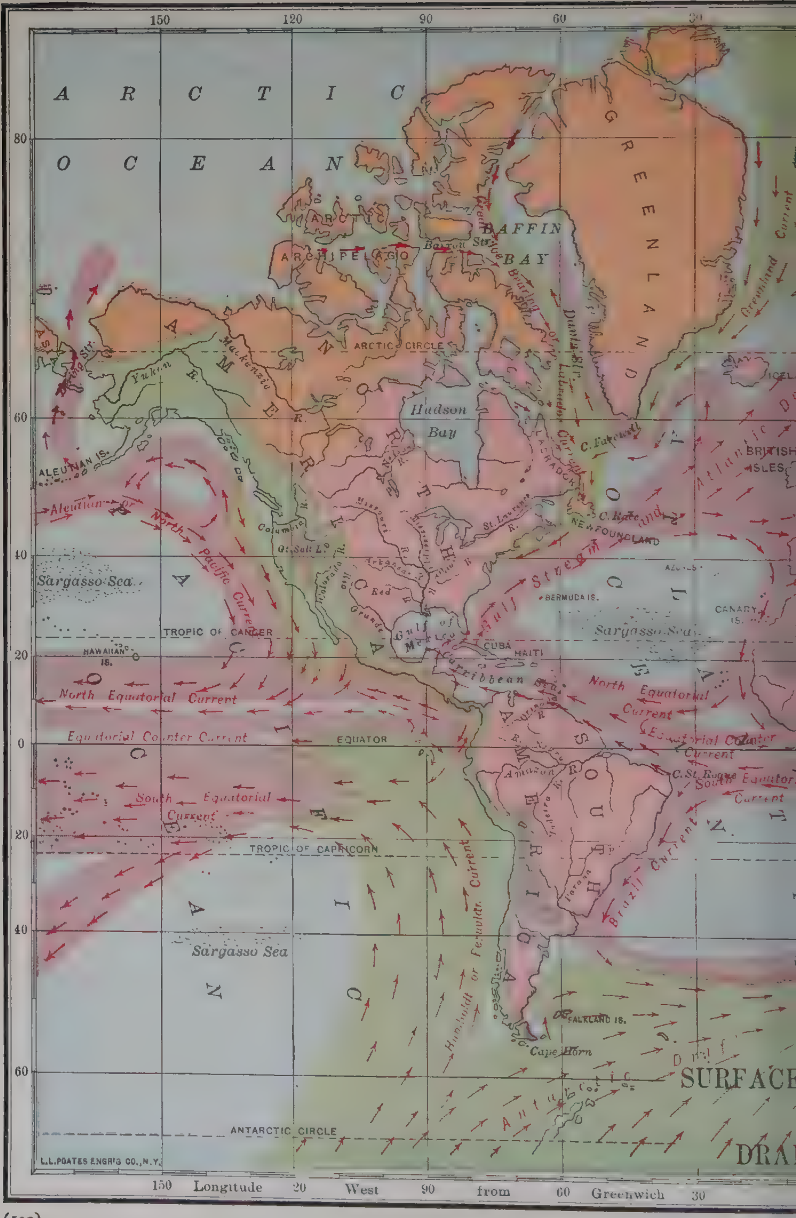
They enter certain river channels with extraordinary velocity. People crossing the dry bed of the river Dee, in England, are sometimes overtaken and drowned by the inrushing water.

The case of the Amazon is of special interest.

The tides ascend this river to a greater distance from the sea than in any other river of the world. They are felt 700 miles up stream; and the singular phenomenon is presented of there being several tides in the river at the same time; for before the flood of one has reached the end of its 700 miles' journey, several other tidal waves, each in succession bringing high tide with it, have had time to enter.

A tidal wave of great height sometimes enters the mouth of a river and ascends its channel as a perpendicular wall of water. Such a tidal wave is known as a *bore.* Among the most remarkable are those of the Hugli at Calcutta, the Garonne in France, the Tsien-tang in China, and the Amazon.

At certain times bores 12 to 15 feet high come rushing into the channel of the Amazon on the top of the tide. Sometimes as many as five, 30 or 40



ARCTIC OCEAN
ARCTIC ARCHIPELAGO
BAFFIN BAY
Barrow Str.
GREENLAND
Hudson Bay
ARCTIC CIRCLE
NORTH AMERICA
SOUTH AMERICA
ALEUTIAN IS.
Aleutian or North Pacific Current
Sargasso Sea
TROPIC OF CANCER
HAWAIIAN IS.
North Equatorial Current
Equatorial Counter Current
EQUATOR
South Equatorial Current
TROPIC OF CAPRICORN
Sargasso Sea
PACIFIC OCEAN
Humboldt or Peruvian Current
Gulf of Mexico
CUBA
HAITI
Caribbean Sea
BERMUDA IS.
Gulf Stream
Labrador Current
C. Farewell
NEWFOUNDLAND
C. Race
AZORES
CANARY IS.
BRITISH ISLES
ICELAND
Greenland Current
Atlantic Drift
C. St. Roque
Brazil Current
FALKLAND IS.
Cape Horn
ANTARCTIC CIRCLE
SURFACE
DRA
L.L.POATES ENGR'G CO., N.Y.
150 Longitude 120 West 90 from 60 Greenwich 30


RRENTS OF THE SEA
AND
E OF THE LAND
EXPLANATION
Drainage into the Arctic Ocean
" " " Atlantic "
" " " Pacific "
" " " Indian "
Land without Ocean Drainage
Cold Currents
Warm "
Counter "
Monsoon "
FRANZ JOSEF LAND
NOVA ZEMBLA
Kara Sea
North Cape
White Sea
NEW SIBERIA IS.
Yenisei
Olenek R.
Lena R.
Indigirka R.
ARCTIC CIRCLE
Bering Str.
NORTH AMERICA
ALEUTIAN IS.
Okhotsk Sea
L.Baikal
Irtish R.
Volga R.
Dnieper R.
Danube R.
Black Sea
Caspian Sea
Lake Aral
TURKESTAN
Amu R.
MONGOLIA
Desert of Gobi
Hoang Ho
Amur R.
Japan Sea
JAPAN
Kuroshiwo
Yangtse-Kiang
Yellow Sea
Sargasso Sea
TROPIC OF CANCER
Mediterranean Sea
Sahara
Euphrates R.
Red Sea
ARABIA
Indus
Brahmaputra R.
Ganges R.
Salwin R.
Mekong R.
Arabian Sea
Bay of Bengal
China Sea
PHILIPPINE IS.
North Equatorial Current
Equatorial Counter Current
Malabar Current
CEYLON
EQUATOR
L. Tchad
Nile
Kongo R.
Victoria Nyanza
SUMATRA
BORNEO
NEW GUINEA
JAVA
Torres Str.
Equatorial Counter Current
MADAGASCAR
South Equatorial Current
TROPIC OF CAPRICORN
AUSTRALIA
L. Amadeus
L. Eyre
L. Torrens
L. Gairdner
Darling R.
West Australian Current
East Australian Current
South Equatorial Current
Mozambique Current
L. Ngami
Orange R.
Good Hope
Agulhas Current
South Atlantic Current
Sargasso Sea
Bass Str.
TASMANIA
NEW ZEALAND
Antarctic Drift
ANTARCTIC CIRCLE
30 Longitude 60 East 90 from 120 Greenwich 150 180

miles apart, dash up the river, capsizing small craft as they go and spreading consternation among the watermen.

The bore of the Tsien-tang is even greater than that of the Amazon. It spans the river with a feather-white and roaring wall of water, 20 feet high, and travels at the rate of eight miles an hour.

The Currents of the Sea. — There are rivers in the sea. They are of such magnitude that the mightiest streams of the land are rivulets compared to them. They are either of warm or cold water, while their banks and beds are water of the opposite temperature. For thousands of miles they move through their liquid channels unmixed with the confining waters. These movements are called *currents*.

The mariner can sometimes detect them by the different color of their stream, while, if they give no such visible sign of their existence, he can trace them by testing their temperature with his thermometer.

Classification and Course of Currents. — The chart on pages 190, 191, exhibits a general view of the horizontal currents.

(1) There is an Equatorial Current sweeping from east to west on each side of the equator, and well-nigh encircling the globe;

(2) There is a slight eastward Counter Current not far from the equator;

(3) There are Polar Currents setting from the polar regions toward the equator;

(4) There are Return Currents setting from the equator toward the poles.

The chart also shows that as in the case of the tidal wave, so in the case of oceanic currents, the shores of continents and islands have marked effect in modifying their normal courses. These are also modified by the rotation of the earth.

If two trains are moving on parallel tracks in the same direction and with the same speed, an object thrown or a ball shot "point blank" from one to the other may strike the point aimed at. But if the train from which the ball is shot be going 35 miles an hour, and the other only 15, the ball from the first will strike in advance of the point aimed at. If the direction of the trains

be eastward, then the ball will strike a certain distance to the east of the point aimed at.

This is what occurs when water starts from the equator toward the poles. It rotates toward the east at the speed of 1000 miles an hour. Passing to either pole, therefore, it has a higher speed of rotation than belongs to the latitudes which it reaches, and hence it has an eastward movement.

If now we suppose the ball to be discharged from the slower train, it will obviously fall behind, or to the westward of the point aimed at. This is what occurs when water starts from either pole to the equator. It has the slower rotary motion of the pole, and, as it approaches the equator, it constantly enters latitudes which have a higher speed of rotation. They pass it by, and it lags to the westward.

Hence currents moving to the poles derive from rotation an eastward trend; those moving to the equator, a westward.

In treating of oceanic currents it is important to observe the methods of naming them. A northeast wind *comes from* the northeast, a northeast current *goes toward* the northeast. In other words, while the winds are named according to the points from which they blow, currents are named according to the quarter toward which they flow.

Currents of the Atlantic. — *The Equatorial Current* crossing this ocean between the shores of Africa and South America strikes the latter continent at Cape Saint Roque. Here it divides. One portion passes southward, following the coast line of South America. It is named the *Brazil Current.* Its waters, reaching the Antarctic regions, are carried back with the polar current which sets along the west coast of Africa, toward the equator.

The other portion of the Equatorial Current, on leaving Cape Saint Roque, flows northwestwardly. It is divided by the West Indies. Its main section enters the Caribbean Sea and the Gulf of Mexico, and from these it issues through the Strait of Florida as the well-known *Gulf Stream.* Its westerly set in the Caribbean Sea is so strong that near the shores vessels can scarcely make headway against it.

Among the return currents which carry the ocean waters from the equator to the poles, the Gulf Stream is the most remarkable. Issuing from the tropics, this current crosses the Atlantic in a northeasterly direction. On leaving the Strait of Florida, it takes a course nearly parallel to our Atlantic sea-

board. Reaching the latitude of Newfoundland, it turns more directly eastward.

Near the Azores it becomes a widely expanded drift rather than a well-defined, riverlike current. Here it divides. One branch passes southward, skirts the western shores of southern Europe and Africa, and then, veering to the westward, finds its way back into the Equatorial Current. The other passes on to the northeast, bathes the shores of the British Isles and northern Europe, and enters the Arctic basin.

The length of the Gulf Stream, from the Gulf to the Azores, is about 3000 miles. Its breadth in the Strait of Florida is about 40 miles. In its progress it constantly increases in breadth, till, in the middle of the Atlantic, it is 120 miles across. The depth is about 2400 feet near the straits. This diminishes as the width increases. Off Charleston it is reduced to 1800 feet.

In volume the Gulf Stream exceeds the Mississippi more than 1000 times.

The temperature of the surface waters of the Gulf Stream, as they pass the Strait of Florida, is sometimes as high as 85° F. It is a river of warm water, and retains its warmth in a remarkable manner. Off Cape Hatteras, and even as far as the Grand Banks, its temperature is 15°, 20°, or even 30° higher than that of the atmosphere.

The storing up of heat begins, no doubt, while the Gulf Stream is still a part of the Equatorial Current, and continues all the time that its waters are exposed to the tropical sun, whether in the Atlantic Ocean, the Caribbean Sea, or the Gulf of Mexico.

From the Gulf up to the Carolina coasts the waters of the Gulf Stream are of an indigo-blue color; and the line which marks the division between them and the edge of the inshore waters is sometimes so sharp that the observer can distinguish when one half of the vessel is in the Gulf Stream and the other is in the cool littoral waters. In short, the line of demarcation is so well defined that navigators in the olden times, when both

instruments and methods for determining longitude at sea were rude, were accustomed to judge of their position by it.

So much heat is conveyed by this stream to northern latitudes, that the winter climate of the whole western face of Europe is softened and tempered by the winds blowing from its surface.

The ponds of the Orkney Isles, though bordering on the parallel of 60° north, owing to this moderating influence, never freeze; and the harbor of Hammerfest, the most northerly seaport in the world, in latitude 70° 40′, is always open.

On the east side of Greenland and through Davis Strait cold *polar* currents come from the Arctic Ocean to replace the warm water carried northward by the Gulf Stream. Off the southern point of Greenland these currents unite and advance as far as the Grand Banks.

Here one portion of the united stream sinks below the warmer and lighter waters of the Gulf Stream, and pursues its course to the tropics as an undercurrent. The other portion turns southwest and follows closely the eastern coast of North America, keeping between the shores and the Gulf Stream, as far south as Cape Hatteras, where it passes under the Gulf Stream and continues its way to the equatorial regions mainly as an undercurrent.

This current supplies the markets of New England with the choicest fish of the sea, and gives to the coast of Maine its singularly cool summer temperature.

At the Grand Banks the Arctic Current meets the Gulf Stream, and, chilling the vapor which rises from its surface, produces the dense fogs which render this part of the ocean so dangerous to navigation.

From the *Antarctic*, as from the Arctic Ocean, there is a constant flow of icy waters into the Atlantic basin. The South Atlantic Current, issuing from the Antarctic Ocean, follows the western shore of Africa, passes northwestwardly, and contributes to form the Equatorial Current of the Atlantic.

Currents of the Pacific have a general resemblance to those of the Atlantic.

An Equatorial Current starts westward from that portion of the ocean lying to the southwest of Mexico. Like the corresponding current of the Atlantic it divides. One branch passes to the southward. Bathing the eastern shore of Australia, it is called the *East Australian Current.* Between Australia and New Zealand it blends with the Antarctic Drift.

The northern branch of the Equatorial Current pursues a course not unlike that of the northern branch of the Equatorial Current of the Atlantic. Passing the Archipelago off the southeast coast of Asia, its main body turns northeastward, and, sweeping past the Japanese Islands, receives from them its name, *Japan Current.* The natives of Japan call it, from the dark blue color of its waters, Kuro-Shiwo, that is, *Black Stream.*

The *Japan Current* is the Gulf Stream of the Pacific. Like that stream, it has the twofold office of watercarrier and heat-bearer. It transfers the water of the central and western Pacific to its northern and eastern portions ; and with its warm waters it softens the climate of the Aleutian Islands, and of the northwest coast of America, just as the Gulf Stream does that of western Europe.

Passing the Aleutian Islands, the main volume of the Japan Current receives the name of the *Aleutian* or *North Pacific Current*, and takes a southeastwardly course. Reaching the coast, it gives to southern Alaska its enormous annual rainfall and its abundant timber growth ; it waters Washington and Oregon ; and then, veering to the westward, becomes again a portion of the Equatorial Current.

A *Polar Current*, passing either under or to the side of a current which enters the Arctic through Bering Strait, flows into the Pacific. Its course, between the Japan Current and the eastern shores of Asia, is like that of the polar current which flows between the Gulf Stream and the shores of America, and, furthermore, like the Labrador Current, it teems with fish, thereby vastly increasing the capacity of China and Japan to sustain their large populations.

From the Antarctic a broad drift flows toward the equator. Off Cape Horn it divides. One branch passes into the Atlantic ;

the other, the *Humboldt* or *Peruvian Current*, enters the Pacific. The Humboldt Current carries its cool Antarctic waters all along the west coast of South America from Patagonia to the Galapagos Islands. These waters, when they touch the equator, are still too cold for the growth of the coral polyp. Hence the whole western coast of South America is without coral reefs or coral formation of any kind; though in the same latitudes, at a distance from the coast, where the waters are warm, coral thrives in the greatest abundance.

Near and at the equator the Humboldt Current is deflected to the westward and becomes part of the Equatorial Current of the Pacific.

Currents of the Indian Ocean. — The Indian Ocean has no such well-defined system of currents as the Atlantic and Pacific. North of the equator the direction of the flow is determined by the monsoons. South of the equator an Equatorial Current, emerging from the East Indian Archipelago, sweeps to the westward. Reaching Madagascar, it branches. The eastern fork passes to the southward and merges with the Antarctic Drift. The western flows along the eastern coast of Africa as the *Mozambique Current*. Leaving the Mozambique Channel, it becomes the *Agulhas Current*, and south of the Cape blends with the Antarctic waters.

A branch of the Antarctic Drift, setting to the northwestward, and becoming the West Australian Current, pours its icy flow into the Indian Ocean.

Causes of Oceanic Circulation. — The chief causes of oceanic circulation are to be found in the winds which, brushing the surface of the water, give rise to superficial currents. These, following the direction of the prevailing winds, are further modified by the shape of the land masses. In this manner there are formed in the sea five great eddies, those of the northern hemisphere moving in a clockwise direction; those of the southern hemisphere in a counter-clockwise direction.

The trade winds blowing incessantly to the westward, and meeting over the equatorial regions, impart to the waters be-

neath them a gentle but continuous westerly movement, hence the *Equatorial Current*, while farther to the north and to the south, under the influence of the prevailing westerly winds, the currents bear to the eastward.

In those parts of the Indian Ocean that are within the monsoon district the currents are controlled by the monsoon winds. For six months they flow in one direction, for six months in the other.

Some winds produce irregular currents. Such effects have been observed upon rivers, ponds, or canals, in piling up the water on one side or at one end, and by blowing it away from the other.

In great storms at sea the winds may drive the water before them and pile it up above its usual level.

It has been held that oceanic circulation is largely due to differences in the specific gravity[1] of the waters in various parts of the sea. That it does exert some influence seems probable, especially in the interchange of water between the equatorial and polar regions.

Sea water when heated expands. A given volume of such heated water, if it contain the same proportion of salts as an equal volume of colder salt water, will weigh less. On the other hand, when sea water is chilled, it contracts and becomes heavier.

The surface temperature of sea water in polar seas is about 35° F; in equatorial, about 80°. This difference of temperature is permanent, and sufficient to produce a marked variation in the specific gravity of the water in the two regions.

Wherever the waters in one part of the sea differ in specific gravity from the waters in another part, no matter from what cause the difference may arise, or how great may be the distance between two such parts of the sea, the heavier water will flow,

[1] Two bodies are said to differ in specific gravity when equal volumes of the two differ in weight. A gallon of salt water, for example, weighs more than a gallon of fresh water. A pint of water weighs about a pound; a pint of quicksilver weighs about thirteen pounds.

by the shortest and easiest route, toward the lighter; and the lighter, in its turn, will seek the place whence the heavier came.

Sargasso Seas. — An interesting evidence of the circulation of the oceanic waters is to be found in what are known as Sargasso Seas, so-called from *sargazo*, the Spanish name for seaweed. These are vast collections of drifting seaweed, which gather in those portions of the different oceans which are most free from the influence of currents.

If bits of cork or chips, or any floating substance, be put into a basin, and a circular motion be given to the water, all the light substances will be found crowding together near the center of the pool where there is the least motion. Like such a basin is the Atlantic Ocean, with its Equatorial Current and its Gulf Stream. The Sargasso Sea is at the center of the whirl.

The Sargasso Sea of the Atlantic embraces an area of several hundred thousand square miles; and though the weeds are all afloat and held by nothing, yet the Sargasso remains where it was over 400 years ago, when Columbus passed through it on his first voyage to America.

During Maury's researches connected with the "Physical Geography of the Sea," the existence of four other Sargassos was established; namely, one in the Indian Ocean, two in the Pacific, and another in the Atlantic. (See Chart, pp. 190, 191.)

PART IV.—THE ATMOSPHERE

XVIII. PHYSICAL PROPERTIES OF THE ATMOSPHERE

The Composition of the Atmosphere.—Wherever we go on the surface of the earth we perceive that air is present. If we ascend above the mountain tops, or pierce the loftiest clouds, it is still with us. It envelops the earth.

The entire mass of the air is commonly spoken of as the *atmosphere.* It is transparent, and, unlike water, is a mixture of gases and not a chemical compound. Its chief ingredients are oxygen and nitrogen. These elements are present in the proportion of 21 parts by weight of the former to 79 parts by weight of the latter, or approximately 1 to 4. In addition there are also present in the air carbon dioxide in small amount, and in lesser degree the rarer gases argon, krypton, and helium. Furthermore, ordinary air contains water vapor and dust in varying amounts as a result of its interaction with the hydrosphere and the lithosphere.

Not only does oxygen form a part of the atmosphere, but chemically combined with hydrogen it forms water, and in combination with several other elements such as silicon, carbon, calcium, and aluminum constitutes the outer portion of the lithosphere. Oxygen is, therefore, the most widely distributed of all the chemical elements. It is, moreover, the vivifying agent of the atmosphere, being essential to the existence of living things.

Nitrogen, of which the atmosphere is largely composed, is to the chemist "inert"; that is, it does not combine strongly with other elements. In this particular it is the opposite of oxygen and consequently does not enter conspicuously into the formation of the earth's crust. Its function in the atmosphere seems to be largely that of a diluting agent, thus preventing the too great activity of the oxygen.

Carbon dioxide, though normally present in the atmosphere in a small

amount, is essential to plant life. It is exhaled by most forms of animal life and is at times generated in great abundance in volcanic regions, especially where vulcanicity is dying out. In large amount carbon dioxide is suffocating rather than poisonous, cutting off the supply of oxygen which is essential to life.

Invisible water vapor is another substance found in greater or less quantity in the atmosphere. It results from evaporation, and is one of the forms assumed by water in its circulation. When chilled, this vapor collects in the form of minute drops, forming clouds, and upon further cooling, may be precipitated as rain, hail, or snow.

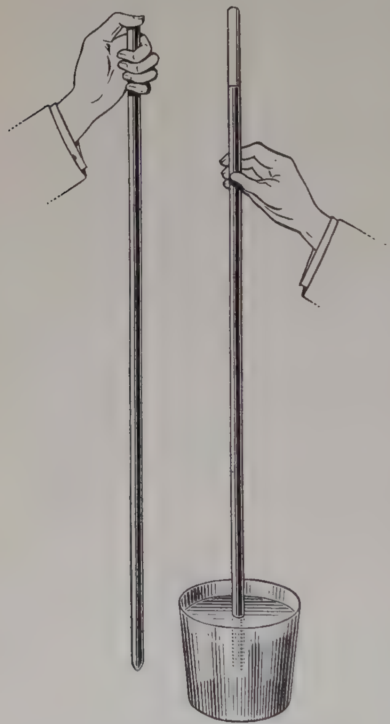
Dust is one of the most common impurities of the atmosphere; and although usually confined to the layers over the land surfaces, it is in some instances, as after certain volcanic eruptions of the explosive type, wafted for long distances in the upper regions of air and even far over the sea. Furthermore, it may be held in mechanical suspension, if sufficiently fine, for a long period — it may be several months. A heavy rainfall cleanses the atmosphere by washing the mechanically suspended particles from it, hence in arid and semiarid regions the air is more heavily charged with dust than elsewhere. Dust, it will be seen, is to the atmosphere what sediment is to water. The agitation of the wind pollutes the air with dust just as the stirring of the bottom of a pond pollutes the water with mud.

From what has been stated it is obvious that the atmosphere over the sea is freest from contamination by solid matter. A microscopic examination of dust deposited from the atmosphere shows it to be composed of a great variety of substances, both mineral and organic, including certain disease-bearing germs.

Origin of the Atmosphere. — If the earth originated in the manner set forth by the nebular theory, we can readily conceive that in its early stages, on account of the prevailing high temperatures, much matter now in the form of solids and liquids was in a vaporous or gaseous state, and that, as a result of such condition, many substances were included in the atmosphere which are not now present. It may be conceived further that by chemical combination and by condensation from cooling — processes continued through a long period of time — the atmosphere would become much reduced in volume and, at the same time, simpler in composition. It is especially noteworthy that, according to this view, the primitive atmosphere must have contained within its body the elements of the

primeval sea, or the first hydrosphere, which came into existence as a condensation from it.

On the other hand, it is held by the advocates of the planetesimal hypothesis that "the substances of the atmosphere and ocean were originally a part of the planetesimals and helped to form the earth's mass," and that they were subsequently forced to the surface by the compression due to gravity and the heat involved in that process.



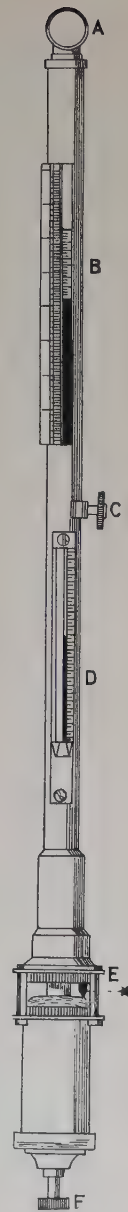
TORRICELLI'S EXPERIMENT

Weight of the Air or Atmospheric Pressure. — Though a gaseous body, the atmosphere is influenced by gravity. Air, therefore, has weight, from which follows atmospheric pressure. The famous Galileo was the first to point this out. A pump maker wished to know from him why a pump would not raise water from a well which was more than 32 feet deep. Galileo concluded that it was because a column of water 32 feet high is as much as the weight of the air can balance.

Everywhere upon land and sea this pressure is felt. If the atmosphere were undisturbed and of the same density throughout, or if it were of a uniformly decreasing density, we might expect it to exert upon all points at the sea level the same pressure. And this it practically does, notwithstanding the fact that it is a medium subject to numerous and, at times, sudden disturbances which do not fail to manifest themselves

in pressure variations. The average atmospheric pressure at the sea level is 14.74 pounds (for convenience usually stated 15 pounds) to the square inch of surface, a pressure exceeding a ton to the square foot.

The Mercurial Barometer. — This is an instrument used for measuring atmospheric pressure. Its construction is based upon a well-known experiment of Torricelli, a celebrated pupil of Galileo. He filled a tube, about three feet in length, with mercury. He then carefully inverted the tube, covering its open end with his thumb, until inserted in a vessel of mercury. When released the mercury fell until it was about 30 inches in height. This column was sustained by the weight of the air.



In Green's Standard Barometer, here shown, the glass tube containing the mercurial column is, for protection, inclosed in a brass case. To the upper end of the case is attached a ring (*A*) for the suspension of the instrument; to the lower end is appended, by means of a flange (*E*), the cistern. Through a slot (*B*) in the case the top of the mercurial column may be seen (obscured in the figure by the vernier which moves in the slot) and its height determined by a scale graduated in inches and tenths of inches. For convenience and more accurate reading the scale is provided with a vernier moved by a milled head (*C*). As mercury is affected by heat, the reading of the instrument must be corrected for various temperatures, hence a thermometer (*D*) is attached to the case. The cistern consists of an upper portion in the form of a glass cylinder through which the surface of the mercury and the lower end of the barometric tube may be seen. The lower portion of the reservoir, also protected by a brass case, consists of a wooden

receptacle terminated with a kid bag which forms the bottom of the mercury-containing vessel. At the lower extremity of the cistern case there is an adjusting screw, worked by a milled head (F), the upper end of which presses against a button attached to the kid bag. When the button is pressed up, the capacity of the cistern is diminished; when it is withdrawn, the capacity is increased. To use the barometer the adjusting screw should be raised or lowered until the surface of the mercury just touches the end of the ivory peg (*), which establishes the zero point of the scale.

Variations in Atmospheric Pressure. — Variations in atmospheric pressure are occasioned by changes of level and by changes in the weight of the air.

(1) *Effect of Change of Level.* — In ascending a mountain, the explorer passes through a certain proportion of the atmosphere, and is, of course, relieved from a portion of its pressure. For the first 10,000 feet of ascent the barometer falls 10 inches — an average of one inch to every 1000 feet of ascent. For the second 10,000 feet the barometer would fall about 6.7 inches, the amount of its fall constantly decreasing as he ascends. Mr. Glaisher in his balloon reached a height of 37,000 feet, and then the barometer went down to seven inches.

The lowest reading of the barometer ever observed upon a mountain was 13.3 inches, at an elevation of 22,079 feet, on the summit of Ibi-Gamin, in Tibet. It is easy to see that the amount of fall furnishes a means of measuring heights of mountains, and altitudes to which balloons ascend.

An interesting consequence arising from the weight of the atmosphere is the fact that the boiling point is lowered at high elevations. At about the level of the sea, water boils at 212° F. At Quito, 11,000 feet high, the boiling point is 194°. On the top of Mont Blanc, nearly 16,000 feet high, it is 180°.

This results from the diminished pressure to which water is subjected at great elevations. It has the inconvenient effect of making it impossible in such situations to cook by boiling.

(2) *Effect of Change in Weight of the Atmosphere.* — A fall of barometer occurs, also, when the column of air above any area be-

comes lighter than usual. This takes place when there is more than the ordinary amount of vapor in the air; because vapor is lighter than dry air. Consequently, the greater the proportion of vapor in the air, the lighter that air will be. A *low barometer* therefore usually indicates a moist, rainy atmosphere. A *high barometer* indicates that the atmosphere is heavy; either because it is dry or because it is dense.

The density, or compactness, of the air of course diminishes with the height. On lofty mountains it is highly rarefied, which means that its particles, being relieved from pressure, are more widely separated from one another than at lower levels.

Persons ascending to great elevations sometimes experience a singular difficulty. The walls of the blood vessels burst, and there is a flow of blood from the nose and ears.

This *mal de montagne*, or *mountain sickness*, as the French call it, is seldom felt at a lower level than 16,000 feet, and balloon ascents have been made to a height of 29,000 feet before any serious inconvenience has arisen from this cause.

Lines drawn through places which have the same barometric pressure at any given time are called *isobars*, from the Greek *isos*, equal, and *baros*, weight.

Probable Height of the Atmosphere.—The height of the atmosphere has not yet been definitely determined. Calculations based upon the decrease of atmospheric pressure for increase of altitude seem to indicate that at the height of about 50 miles the air would become too light to affect the barometer appreciably. This would apparently fix the outer atmospheric limit. On the other hand, there is reason for thinking that the atmosphere has a height much exceeding 50 miles. It is believed that meteors become visible only after entering the atmosphere. Observations made upon the same meteor from different points afford data for the calculation of its height. But since the meteor is luminous, this height must represent a distance within the atmosphere. From calculations of this character it is now thought that the atmosphere may even exceed 100 miles in height. While in its outer layers the atmosphere must exist in an extremely rarefied state, there is the possibility that some of its rarer elements may exceed the greater limit given above.

Atmospheric Temperature. — The process by which the air is warmed is complicated and for that reason can be best understood by the separate consideration of each step.

(1) A portion of the radiant heat emitted by the sun is intercepted by the earth. In its passage through the atmosphere a part of this heat is absorbed, thus increasing the *temperature* of that body.

(2) The layer of air resting directly upon the terrestrial areas, which have become heated by the impingement of radiant heat, are warmed by contact with the heated surfaces (conduction).

(3) The lowest stratum of air, thus warmed and expanded, is crowded from its position and borne upward by the settling of the cooler, and therefore heavier, air. In this manner currents are established (convection) which circulate to a limited height; that is, until the warm ascending air is cooled to the temperature of the air above it.

(4) Of the radiant heat falling upon the water areas a large part is reflected, and passing outward through the atmosphere again contributes to its warming by partial absorption. This also may become a source of atmospheric movement.

(5) On the other hand, while the land areas are poor reflectors, they emit radiant heat from which, as it passes outward, the air exacts a contribution.

(6) In the heating of the lower atmosphere the absorption of radiant energy by the dust particles plays an important part. As they become heated, they in turn heat the air that surrounds them.

(7) Another source of atmospheric heat which must be taken into consideration is the absorption of heat radiated from the earth by watery vapor. In this particular watery vapor is said to be more efficient than any other atmospheric ingredient. Clouds act as a protective covering, thus preventing the too rapid cooling of the lower atmospheric layers and the disastrous results that would arise from it.

Temperature of the Air as affected by Night. — It is during the day that the heat effects of solar energy are most pronounced.

At night the heated land surfaces are cooled by radiation, for like other good absorbers, they readily part with their heat, which radiated outward into the air serves in part to prevent its too rapid cooling. As the land cools, the adjacent air also cools by radiation to it, and the layer resting directly upon the ground is further cooled by contact (conduction). This is well illustrated during the winter season when the warming of the ground in the daytime is not sufficient to prevent its freezing at night. Then the air in contact with the frozen surface is itself reduced in temperature.

Water, on the contrary, is a good reflector of solar heat, a poor absorber, and likewise a poor radiator. The little warming that takes place on the surface of the oceanic areas is not readily lost by radiation, in consequence of which there is not the reduction of temperature at night noticed on land surfaces, nor is the air in contact with the water so thoroughly chilled by conduction. Hence it follows that the range of atmospheric temperature over the water is not so great as over the land.

Seasonal Variation in Temperature. — The temperature of the air nearest the earth also varies with the season, being warmer in summer and cooler in winter than in either spring or autumn.

The amount of radiant heat received by any portion of the earth's surface depends upon the directness of the solar rays. When they fall vertically they give rise to the greatest heat effects; as their inclination increases these effects diminish. At the time of the vernal equinox the direct rays fall upon the equator. As spring merges with the northern summer the direct or vertical rays fall upon portions of the earth's surface successively nearer to the Tropic of Cancer until at midsummer (June 21) their northern limit is reached, after which, as has been already explained (see p. 27), their recession southward begins. During this season the heat received by the earth is furthermore increased by the long exposure due to the lengthened days. In the meantime the amount of heat lost by radiation during the night is greatly diminished, owing to the shortness of that inter-

val. Thus the surface warms to summer temperature. Under these conditions, without diminishing the importance of other processes, special emphasis must be placed upon the heating of the lower atmospheric layers by their contact with the heated land areas.

Although midsummer is June 21, the highest temperatures are usually experienced some weeks later. This is due to the fact that the earth, warmed in excess of its radiation, is still receiving radiant heat. As the season advances, however, on account of the increased inclination of the solar rays and the shortening of the days, high temperatures cannot be maintained, hence the earth becomes cooler. This and the attendant phenomena serve also to reduce the temperature of the air.

In the winter season the radiation from the earth is in excess of the warming due to the sun's energy. The earth now becomes chilled, and as a consequence the temperature of the air in contact with it is likewise lowered. Just as the heat of summer comes later than midsummer, so the cold of winter comes later by a few weeks than midwinter (December 22).

Instruments used for Measuring Temperature. — The instruments used for measuring the hotness or temperature of the air, as well as that of other bodies, are termed *thermometers*. The ordinary forms are based upon the expansion and contraction of liquids when influenced by heat or cold. Practically the liquids employed are limited to mercury and alcohol — to the former on account of its high boiling point and to the latter on account of its low freezing point. In the less common metallic thermometers the measurement is made through the unequal expansion of thin strips of different metals, and in one instrument, at least, through a combination of the expansion of a liquid and the elasticity of a metal.

The mercurial thermometer is that in common use. It consists of a capillary glass tube having at one end a bulb or reservoir. In the process of manufacture both the bulb and the tube are filled with mercury which is heated to the boiling point. The tube is then sealed. When cooled the mercury will settle, filling the bulb and a part of the tube.

The methods of graduating the mercurial thermometer or making the scale by which it is to be read, are as follows: Two points are selected as standards — the freezing point and the boiling point of distilled water, the latter under the pressure of one atmosphere, for the boiling point varies according to atmospheric pressure. These standards have been selected, as they can be easily established on any thermometer. According to the Fahrenheit scale (marked F. or Fahr. on the thermometer) the freezing point has been arbitrarily placed at 32° and the boiling at 212°, from which it follows that 180° intervene between the two standard points. According to the Centigrade scale (marked C. on the thermometer), which is simpler, the freezing point has been placed at 0° and the boiling point at 100°. The degrees of this scale, it will be seen, are larger than those of the preceding, the relation being 100 to 180. These are the scales in common use, and they may be either stamped upon the thermometer case or etched upon the glass tube. The latter plan is preferable and is pursued in graduating the best instruments.

Cheap thermometers are useful in a general way, but accurate readings should not be expected from them. Furthermore, if trustworthy results are to be obtained, the thermometer must be properly located. It should never be placed where the air will be influenced by any warming body, and especially should it be protected from the direct rays of the sun. If possible, it ought to be hung in a shelter, raised above the ground, and placed apart from buildings, so constructed as to permit the ready circulation of the air. When this cannot be done, the shelter may be built out from the north window of a building, if in other respects the location is desirable.

XIX. CLIMATE

Weather and Climate. — The atmospheric conditions prevailing at a place during a given time — a day, a month, or even a year — constitute its *weather*. Within this term are included various elements ordinarily perceptible to the senses, such as temperature, moisture or dryness, clearness or cloudiness, the presence or absence of wind. *Climate* is more comprehensive, as it includes "an aggregate of weather conditions" based upon observations extending over a series of years. The longer the periods of observation, the more valuable become the data upon which climate is established.

The chief elements of climate are temperature and moisture, of which the more important is temperature.

The principal causes which modify temperature are, distance from the equator; distance from the sea; prevailing winds and ocean currents; and height above the sea level.

Distance from the Equator. — The first and most apparent cause of the differences in climate is the distance from the equator. This has two effects: As the distance increases, (1) the average annual temperature falls; and (2) there are greater contrasts between summer heat and winter cold.

As the area within the tropics receives the vertical rays of the sun, it is the region of the greatest heat. Between the tropics and the polar circles the sun's rays fall obliquely and therefore exert a feebler power. Within the polar circles the inclination of the sun's rays is greatest, hence, except during a brief period of a few weeks, excessive cold prevails.

The contrasts between summer heat and winter cold are mainly due to variations in the length of the day, and these depend on distance from the equator. Within the tropics there

is comparatively little difference between the two periods of day and night through the year. Only twice in the year, at the equinoxes, are they equal for other parts of the globe.

As the sun passes northward from the equator, the day lengthens over the northern hemisphere, until, within the Arctic circle, the sun does not set at midsummer. The same phenomenon occurs in the southern hemisphere, after the sun passes southward of the equator.

Since there is very little difference between day and night at the equator, the temperature within the tropics is nearly uniform throughout the year.

North and south of the tropics there are important differences between day and night, in consequence of which climatic contrasts are found in all regions outside of the tropics.

Within the polar circles these contrasts are at their maximum. The Arctic summer, strange to say, is exceedingly warm. It is marked by a rapidity of plant growth that is marvelous. In a few weeks crops mature which require twice that length of time in latitudes much nearer the equator. But, on the other hand, the winter cold is correspondingly excessive.

Distance from the Sea. — In certain countries climate is affected more by distance from the sea than by distance from the equator.

The climate of a region adjacent to the sea is called an *insular* or *maritime* climate. The climate of a region remote from the sea is called an *inland* or *continental* climate.

Certain causes moderate insular climates.

(1) Water absorbs heat much more slowly than the land, and therefore remains, in hot weather, comparatively cooler. Hence the summer temperature of a country bordering on the sea is lowered.

(2) On the other hand, water parts with its heat by radiation much more slowly than the land, and therefore remains in cold weather comparatively warmer. Hence the winter of a maritime country is moderated.

(3) Vapor is incessantly rising from the sea, and, being con-

densed, falls as rain or snow upon the land, and this liberates latent heat.

(4) The vapor in the atmosphere of a maritime climate prevents the escape of heat. It acts as a blanket. A familiar illustration of this is the fact that frost rarely occurs on cloudy nights.

(5) Again, the process of evaporation goes on more rapidly in hot weather than in cold, and this has the effect of moderating the summer heat of a maritime country.

For the above reasons, insular or maritime climates are equable, or free from extremes.

Inland or continental climates are the opposite of maritime. They are subject to great extremes, intense heat in summer and excessive cold in winter.

Two reasons may be assigned for this: —

(1) Countries far from the sea are without its cooling influence upon their summer heat, and they have no reservoir of warmth to compensate for their rapid radiation of heat in winter.

The continent of Asia affords the most striking instances of the excessive character of inland climates. The Russian army advancing toward Khiva in 1839–40 experienced vicissitudes of temperature from a heat of over 100° F. to a cold of 45° below zero.

At Werchojansk, eastern Siberia, the culminating point of excessive climate in all the world is reached. The extreme temperature of 90.4° below zero has been observed there. The soil is permanently frozen to the depth of 380 feet. In the month of June the Lena is free from ice; the surface soil has thawed for three or four feet; and the warmth of the short summer is such that grain will ripen in the shallow stratum of soil above the frozen mass. The mean temperature of July at Yakutsk is 69°, the same as at Paris.

(2) The comparative dryness of the air of an inland region contributes to create extremes. This is strikingly illustrated by the climate of the Sahara. The air there is perfectly dry. No vapor hinders the reception of heat by day or its loss by night. Travelers who have suffered from intense heat during the day have found the water in their canteens frozen before morning.

Prevailing Winds and Ocean Currents. — The climate of a country is also greatly modified by the prevailing winds and the

neighboring ocean currents. If the prevailing winds come from the sea, they temper the extremes of heat and cold. If a cold current bathes any portion of the shore, it lowers the temperature; a warm current raises it.

The British Isles and the province of Labrador are the same distance from the equator, and in many parts the same height above the sea. Yet such is the difference of climate between them, that Labrador is covered with snow for nine or ten months every year, and is so cold as to be almost uninhabitable; while in England the ground is rarely covered with snow, and the pastures are green all the winter.

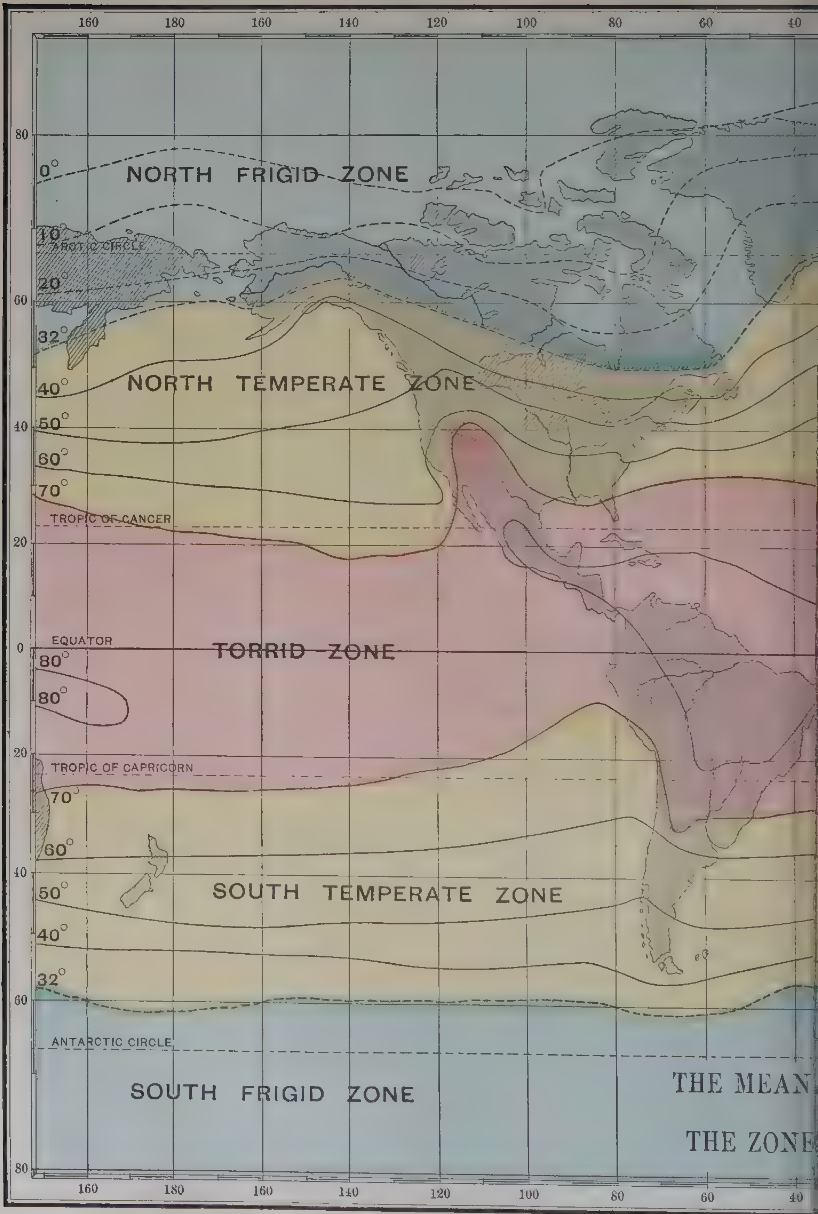
Both countries are in the regions of westerly winds; but in Labrador they come from the land, and are dry and cold; in England they come from the sea, and are laden with moisture and warmth. The shores of Labrador are washed by a cold Arctic current; those of Great Britain by the warm waters of the Gulf Stream and Atlantic Drift.

The climates of western Europe, from North Cape to the Strait of Gibraltar, are modified by the sea winds and the influence of the Drift.

Norway stretches beyond the 70th degree of north latitude; yet the westerly winds are so richly laden with warmth and moisture from the waters of the Drift that the harbor of Hammerfest, latitude 70° 40′, is never frozen, even in the severest winters. But cross the Scandinavian mountains, and there is encountered at once, if it be winter, the severest cold. In this short distance from the warm waters and the west winds of the Atlantic, the Russian lakes and rivers, the gulfs and bays of the Baltic, are found closed to navigation every year from November till May.

Climatic conditions similar to those which affect the western shores of Europe are found upon the western slopes of Oregon, British Columbia, and Alaska. Westerly winds prevail, and they are laden with moisture from the Pacific Ocean. The result is that here, as in Norway, open harbors and evergreen hills are found in the high latitudes of Alaska and other parts of our northwest coast.

Height above the Sea Level. — Among other circumstances, climate depends upon height above the sea. A change of ele-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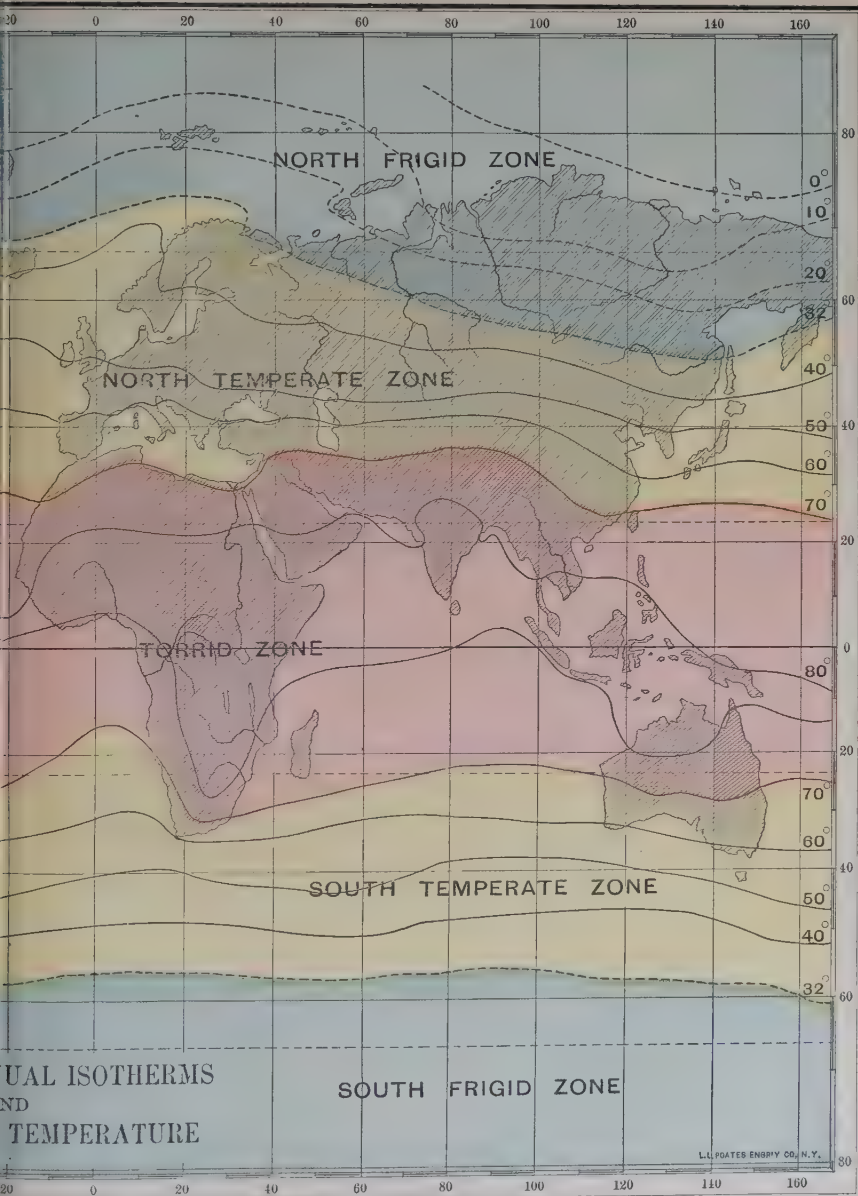
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vation of a few thousand feet at the equator produces a change of temperature as great as would be experienced in sailing 6000 miles to the frozen regions of the poles.

The island of Cuba and the Mexican mountain of Orizaba are in the same latitude. The summit of the mountain is covered with snow all the year; the island with fruits, flowers, and evergreens.

The reason why elevation above the sea level causes reduction of temperature is that the radiation of heat goes on from elevated parts of the earth's surface more freely than from its lower portions. Two causes may be assigned for this: (1) elevations are comparatively small, and therefore have a smaller store of heat; (2) the air and vapor upon elevations are rarefied, and hence little hindrance to radiation is presented.

The general rule as to the effect of elevation is this: for every one hundred yards of perpendicular ascent there is a decrease of one degree in the temperature; so that, even at the equator, by ascending to the height of about 16,000 feet above the sea, one may reach the snow line.

Isothermal Lines. — From thermometric observations made in all parts of the world, the actual distribution of temperature over the globe has been ascertained. To show this, Humboldt constructed a series of lines called *isotherms*, or *lines of equal heat.* These are drawn round the globe so as to connect all places which have the same mean temperature during the year or any given part of the year.

Isothermal lines are far from coinciding with the parallels of latitude. Let us take by way of illustration the line in the northern hemisphere indicating the mean annual temperature of 50°. (See chart, pp. 214, 215.) It passes through Oregon on the Pacific shores, and leaves the Atlantic coast between New York and New Haven. It bends northward in crossing the Atlantic, and in Europe passes near Liverpool, Vienna, and Odessa, and in Asia, near Peking.

The summer isotherms cross Great Britain as east-and-west lines. The winter isotherms are nearly north-and-south lines.

We are not to conclude, however, that because the same isothermal line passes through two places, they have a climate identically the same. Of two such places one may have an extremely hot summer and a correspondingly cold winter. The other may have a climate free from extremes. Yet both may have the same average yearly temperature.

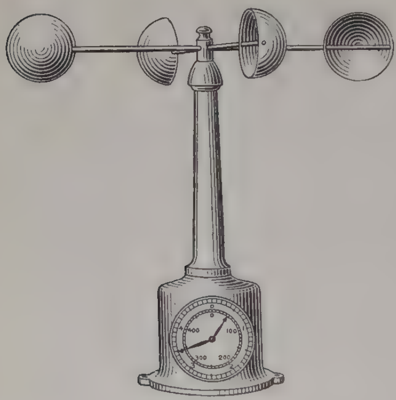
San Francisco and Washington have the same mean annual temperature, while their climates differ greatly.

Again, the same isothermal line passes through New York and Dublin. Yet the climates of these places have no resemblance. The mean winter temperature of Dublin is 6° above that of New York; while the summers of the two places are so unlike, that whereas grapes and Indian corn are successfully cultivated in the vicinity of New York, they will not ripen in the open air at Dublin.

Zones of Temperature. — By means of isotherms we define the zones of temperature. They are indicated by the colors on the chart. The true *Torrid Zone* is bounded by the isotherms of 70° on either side of the equator. The true *Temperate Zones* extend from the isotherms of 70° to those of 32°; the *Frigid Zones* from these to the poles.

XX. ATMOSPHERIC CIRCULATION

Winds. — A body of air in motion is called a wind. The rate of motion and the direction of winds vary greatly. By means of an instrument called the anemometer, it has been ascertained that the velocity of a light wind is 5 miles an hour; of a stiff breeze, 25 miles; of a storm, 50 miles; and of a hurricane, 80 to 100 miles, or even 100 to 150 miles.



ANEMOMETER

This instrument, which is used for determining the velocity of the wind, is placed in an unobstructed, elevated position, as above the roof of a high building. It consists of four hollow hemispherical cups mounted vertically on arms which are attached to a vertical axis. The lower portion of this axis communicates the motion of the rotating cups, by means of an endless screw, to a series of dials which register the number of revolutions.

Again, the direction in which winds blow is so constantly changing that they are often spoken of as fickle, inconstant, and uncertain. There is, however, order in the movements of the atmosphere. The fickle winds are obedient to laws. There are causes that make them blow with greater or less rapidity; there are reasons why they blow now north or south, now east or west.

Winds are named according to the quarter from which they blow. A west wind comes from the west; an east wind from the east.

Cause of Winds.—The chief cause of winds is the unequal distribution of heat in the atmosphere. The underlying principle is illustrated by the following examples.

If a fire is lighted on the hearth, the air within the chimney will be heated and forced upward by an indraught of cooler and heavier air from all parts of the room. This continues as long as the fire burns.

The same occurs when a bonfire is lit, or a house is on fire. Every child knows that "the sparks fly upward to the sky." They are carried up by the hot ascending currents. The air above the fire is expanded, rendered lighter, and driven upward by currents of cool air that come rushing in from all sides. These, when heated, ascend with such force as to carry up clouds of smoke and sparks.

This unequal distribution of heat, as in the warming of the air within the chimney while that in the room is comparatively cold, establishes a system of air currents. If there are no obstacles in the way and if these currents are neither chilled nor heated in their course, they will go straight toward the mouth of the chimney. Chairs and tables as well as other objects in the room will deflect them and cause more or less irregularity in their direction.

To prove that such currents really do flow, place a lighted candle in the doorway of a room in which a fire is burning. The flame will be drawn inward by the current.

Now what occurs in the air of a room when a fire is kindled on the hearth takes place in the atmosphere. Some portions of it are always more heated than others; and the unequal distribution of heat establishes a system of currents. The heated surface of the earth warms the air above it. This air, forced up by the surrounding cool air, ascends as a current; and streams of cooler, heavier air flow in. In proportion to the size of the area heated, the volume of the inflowing currents will be greater or less, and in proportion to the difference of temperature between the heated air and the inflowing currents, the rapidity of their flow will be greater or less.

General Circulation of the Atmosphere. — Turning now our attention from these simple illustrations to the general circulation of the atmosphere, we find that within the tropics there is perpetual summer. Here the air is heated and filled with watery vapor, while the air on either side is cool and comparatively dry.

What must be the effect of this unequal distribution of heat and vapor? There can be but one answer: it creates a general circulation of the atmosphere. In the first place, as in the case of the fire upon the hearth, the heated, moist air of the tropics is pressed upon by the heavier air on either side. It is forced upward, and there is an indraught both from the north and the south to supply its place.

Circulation of the Atmosphere

If the earth were at rest, and if its surface were covered with water, the inflowing currents would go straight from the polar to the equatorial regions. There would then be a simple circulation of light air from the equator to the poles, and of heavy air from the poles to the equator. The winds would be steady and unvarying.

But the earth is not at rest, and its surface, instead of being uniformly covered with water, is varied by land masses of greater or less magnitude and elevation. The rotation of the earth and

the influence of its land masses are two causes which largely affect the circulation of the air and render it exceedingly complicated.

Winds are classified, according to the regularity with which they blow, as *constant*, *variable*, and *periodical.*

Constant or Trade Winds. -- Certain of the winds blow without interruption in the same direction and at nearly the same rate. So constant are they that vessels often sail in them for days without, as the sailors say, "changing a stitch of canvas." It was the steady blowing of these winds which so alarmed the crew of Columbus on his first voyage to America, and led them to fear that they would never get back to Europe. From their always pursuing one *trade*, *i.e.* path, or from their importance to navigators, these winds have been called *trade* winds, or the trades.

If the earth had no daily motion, these winds would blow on one side of the equator from the north; on the other side from the south; and in both instances, directly into the equatorial regions. But, in consequence of diurnal rotation, the air, when it arrives at the equator, is in a region which is moving toward the east 120 miles an hour faster than in latitude 30°, where it began to blow as trade winds. In thus passing from regions of lesser velocity to a region of greater velocity the trade winds are deflected toward the west, becoming in the northern hemisphere northeast winds and in the southern, southeast winds.

Variable Winds. — North and south of the trades are the zones of the so-called variable winds. They extend from the parallels of 30° north and south, to the polar circles. Within these limits the prevailing direction of the winds is *counter* or opposite to that of the trades; that is, from the southwest in the northern, and from the northwest in the southern hemisphere. For this reason these winds are called *counter trades.* They are also known as *anti-trades* and *prevailing westerlies.*

Their origin is thus explained: While the trades blow steadily from the poles, there must be return currents from the equator to the poles, otherwise the polar regions in time would

be destitute of air. When the upward current at the equator has risen to a considerable elevation it divides and flows toward the poles, one part going toward the north, and the other toward the south pole.

These two streams of air remain upper currents as far as the northern and the southern limits of the trade winds; that is, about as far as the parallels of 30° north and south. Here, for the reason that their temperature has fallen below that of the air inflowing from the poles, they descend and blow as surface winds. They become *variable*, since they are frequently interrupted by great swirls or cyclonic movements following in the same general course; that is, from the southwest to the northeast.

That the upper currents above alluded to do flow out northward and southward from the equatorial regions is abundantly proved. Sometimes volcanoes, as we have already learned, eject vast quantities of dust. Not unfrequently this passes into very elevated regions of the atmosphere; and instances are on record of its being carried sometimes for hundreds of miles in a direction opposite to that of the surface winds.

Conseguina, in Nicaragua, is in the region of the northeast trades. During the eruption of 1835, its ashes were carried to the island of Jamaica, distant 800 miles to the northeast. No other explanation of this seems possible, than that an upper current was blowing above the surface winds, in an opposite direction.

In 1815, ashes from a volcano in the island of Sumbawa, near Java, were borne to the island of Amboina, 800 miles to the northeast, although the southeast monsoon was then at its height. This again proves that there must have been a powerful current toward the northeast, above the southeast surface wind. It is clear, therefore, that return currents flow from the equator to the poles.

Were it not for the earth's rotation, the counter trades would move straight to the poles. They are, however, influenced by that force and so deflected as to blow from the southwest or west. This is explained as follows: In the equatorial regions these winds have acquired the rapid rotary motion toward the east which belongs to that portion of the earth. Hence, when they reach the latitudes nearer the poles, they are blowing east-

ward with a velocity far more rapid than that belonging to those regions, and thus become westerly or southwesterly winds.

The polar winds are currents of cold air making their way from the poles toward the equator. Their direction is similar to that of the trade winds, northeast in the northern hemisphere, and southeast in the southern hemisphere. Coming from the equator, the counter trades bring moisture and warmth; the polar winds are dry and cold.

The trades, counter trades, and polar winds, though treated separately, are really only parts of a great atmospheric movement which is ceaselessly accomplishing its unending circuit from the equator to the poles, and from the poles back to the equator.

The Calm Belts. — Between the northeast and the southeast trade winds there is a belt of calms encircling the earth known as the *Equatorial Calm Belt.* The name is not altogether good, for throughout the entire region a vast current of air is ascending. It is therefore an area of low barometric pressure, and is calm only in the sense of being comparatively free from the horizontal movements of the atmosphere or those that are ordinarily recognized.

The portion of this belt resting upon the sea is the most difficult part of the ocean for sailing vessels to cross. By sailors it is called the *doldrums*. Ships are sometimes detained here many days.

Between the trades and counter trades, in each hemisphere, there are also belts of atmosphere marked by the prevalence of calms. The belt in the northern hemisphere is known as the *Calms of Cancer;* that of the southern, as the *Calms of Capricorn.* These calms, where they occur on the ocean, are termed by seafaring men *horse latitudes*. Here, unlike the Equatorial Calm Belt, the air currents are descending and the area is one of high barometer.

The position of all the calm and wind belts above described is not invariably fixed. They all move northward and southward, following the apparent course of the sun. They reach

their farthest northward limit in autumn, their farthest southern limit in spring.

The Periodical Winds are those which blow for a certain time in one direction, and then for an equal or nearly equal time, in the opposite direction. They are the *land* and *sea breezes* and the *monsoons.*

Along the coast of most countries there is a breeze from the sea by day and from the land by night. The rays of the sun heat the land more readily than they do the water. The warm rocks, sand, and soil heat and expand the air in contact with them, rendering it light. Pressed upward by the cooler air of the sea, it rises. Currents then rush from off the sea to supply the place of the ascending columns, precisely as the indraught to a furnace supplies the rush up the chimney. Thus a sea breeze is produced.

At night this action is reversed. The land has the property of radiating, that is, of parting with, its heat more rapidly than the water, hence the land by night grows cooler than the sea. It then cools the air above it. But the air over the sea remains comparatively warm and light and is therefore pressed upward by the cool air from the land in the form of seaward-blowing currents. They constitute the land breeze.

Were it not for these refreshing breezes, many countries along the seacoast would be uninhabitable.

Monsoons are winds which blow from a certain direction for part of the year, and for the rest of the year from quite another quarter. They are land and sea breezes on a grand scale. Instead of alternating with day and night, they alternate with summer and winter, hence their name, from an Arabic word meaning *season.*

The most famous monsoons are those of southern Asia. In India they blow from the northeast for six months of the year, and from the southwest for six months.

During the summer the sun plays upon the great deserts and inland basins of central Asia. Those dry and barren wastes glow like furnaces, and the heated air ascends from them in

immense columns. A disturbance is created which is felt to the distance of 2000 or 3000 miles from its center. Cooler air rushes in from the sea on three sides of the continent. Along the coasts of Siberia it comes from the north. From China round the south of the continent to the Red Sea, it comes from the Pacific and Indian oceans; that is, from the southeast, south, or southwest.

In this region, which is largely in the zone of "trades," the effect is so great as actually to reverse the trade wind and cause it to blow in the contrary direction.

In the winter the center of Asia is a region of low temperature. Its atmosphere is dry, cold, and heavy; that of the seas south and east of the continent is moist, warm, and light. The light air is pressed upward by the heavy, and ascends into the upper regions of the atmosphere. Currents then blow from the land toward the sea. In consequence of this we have, during the winter in India, the northeast monsoons, which are really the northeast trades blowing with augmented force and velocity; on the Chinese coast we have the northwest monsoons.

The summer or the southeast and southwest monsoons, having passed over the sea, are laden with moisture, and are the *wet* monsoons. They give its *wet* season to southern Asia. The northeast and northwest monsoons are for the most part dry, because they come from the land. During their prevalence it is the *dry* season. The changing from the dry winds to the wet is called in India the "bursting" of the monsoon.

The southwest monsoon sets in generally toward the end of April, a steady wind sweeping up from the Indian Ocean and carrying with it dense volumes of vapor. The atmosphere becomes close and oppressive. Flashes of lightning play from cloud to cloud. The wind suddenly springs up into a tempest. Then a few great heavy drops of rain fall; the forked lightning is changed to sheets of light, and suddenly the flood gates of heaven are opened, and not rain, but sheets of water, are poured forth, refreshing the parched earth, carrying fertility over the surface of the country, filling the wells and reservoirs, and replenishing the dwindling rivers and streams. The whole land from Cape Comorin to Bombay seems suddenly recalled to life.

Certain other winds resembling the monsoons are those of Australia, the Gulf of Guinea, and the Mediterranean. They are sometimes called minor monsoons.

The winds of Australia blow landward in the hot months; seaward in the cold season. They are largely controlled by the great desert of Australia at the one season and by that of Gobi at the other. During the South Temperate summer the Australian desert is the hotter. During the South Temperate winter Gobi is the hotter. Each thus becomes in turn the controlling area.

The Australian monsoons, however, do not compare in regularity with those of India.

Over the Gulf of Guinea and the Mediterranean periodical winds blow in summer in opposite directions; the winds of the Gulf of Guinea come from the southwest, those of the Mediterranean — known to the ancient Greeks as the Etesian winds — are from the northeast. Both are due to one cause, namely, the intense heating of the Sahara. This produces an upward current of heated air and an inrush of cooler air from the Gulf of Guinea on the one side, and from the Mediterranean on the other.

The periodical winds of Mexico, Central America, and the Brazilian waters, and those known in Texas as "Northers," are due to causes similar to those of the monsoons.

Among the periodic winds of less importance are the return currents from deserts. These are laden with heat, sand, and dust.

From the Sahara currents flow northward and southward. Those from the south enter Egypt, and blow for a few days at a time during a period of 50 days. Hence they are called *khamsin*, an Arabic word meaning fifty. During their prevalence the air is filled with blinding dust and the midday sun is darkened. By such a wind of unusual violence, the army of Cambyses, 50,000 in number, is said to have been destroyed, when on its way to attack the oasis and temple of Jupiter Ammon.

Crossing the Mediterranean, the desert wind scorches the vegetation of southern Europe. It is known as the *sirocco*.

The tops of mountains chill the surrounding air. This sometimes descends as a cold wind into the warmer regions below. Thus from the snowy heights of the Andes the cold *pamperos* sweep over the Pampas of the Plata, the icy *puna* descends upon the table-land of Peru, and the chilling *mistral* descends from the Alps to the shores of the Mediterranean, causing great discomfort to sick and well.

SAND DUNE AT DUNE PARK, INDIANA
Showing the general level surface and the steep lee slope encroaching on a pine forest.

Surface Effects of Winds are especially well shown along sandy coasts and in arid regions. By the constant blowing of the wind sand is accumulated in rounded ridges, like snowdrifts, called dunes. These heaps are by no means stationary, but advance with the wind, sometimes overwhelming forests and converting arable lands into barren wastes. Large dunes are found on the southwest coast of France. Here for

SURFACE OF DUNE, DUNE PARK, INDIANA
Showing the destruction of a forest by dune invasion. (From United States Geological Survey.)

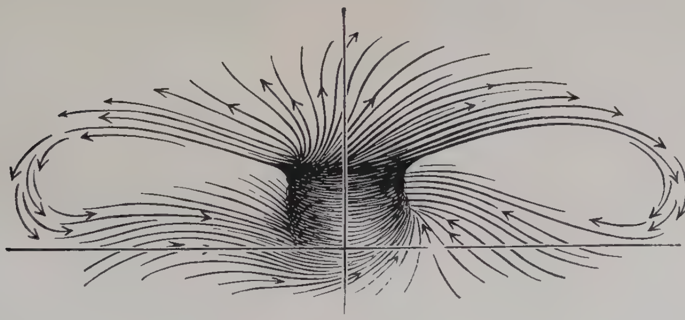
the distance of 150 miles they cover a strip several miles wide, attaining in some instances the height of 300 feet. At the head of Lake Michigan and on its eastern shore are found large dunes. On the Pacific coast, near the Golden Gate and elsewhere, the drifting of the sand has been prevented by the cultivation of certain plants. The heaping up of sand ridges in desert regions through wind action is also common, as in Africa, Arabia, and the Great Basin. Moreover, blowing sand is an agent of abrasion and by it even rocks are worn away.

Among other surface effects of wind mention may be made of the stripping of land surfaces, the transportation of dust, and the destruction of forests.

XXI. STORMS

General Description. — Storms and tempests are sudden and violent disturbances of the atmosphere. At sea they are among the most grand and terribly sublime spectacles in nature. A wind becomes a storm when it attains the velocity of 50 miles or more an hour.

The great storms of the West Indies and of the Indian Ocean are called hurricanes; those of the China Sea, typhoons. These storms, which are alike in cause and character, together with the great eastward-moving swirls of the temperate regions, may be considered under the general name of *cyclone*. This word, derived from the Greek *kuklos*, circle, refers to the fact that they consist of columns of air revolving round a perpendicular axis.



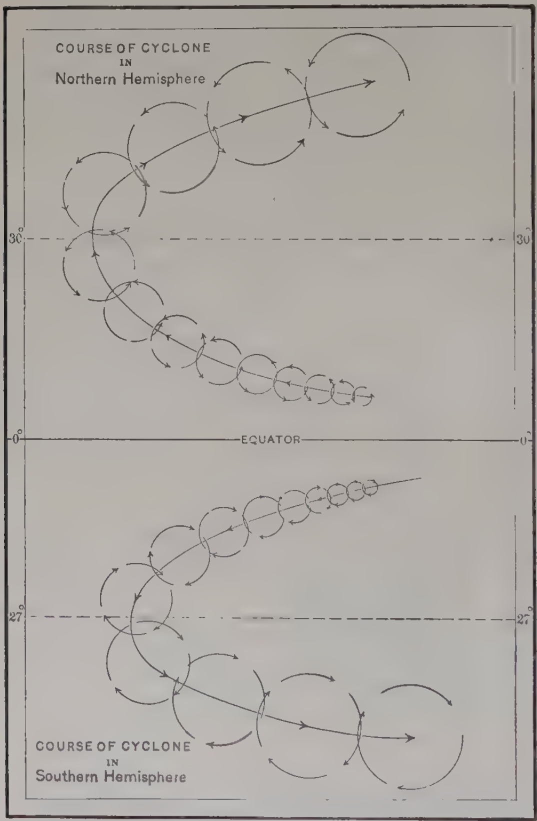
SKETCH TO ILLUSTRATE THE LOWER-ATMOSPHERIC CIRCULATION IN A HURRICANE
The inward spiral at the base is the surface wind. (After Everett Hayden in *National Geographical Magazine.*)

At the same time they have a progressive motion of greater or less rapidity over a certain portion of the surface of the earth.

Cause of Storms. — The general cause of all such atmospheric disturbances is the same in principle as that of ordinary winds.

It is a difference or inequality of pressure or weight, in different regions of the atmosphere. The principle may be thus stated: Into an area of low barometer a wind must always blow from an area of high barometer.

When from any cause the weight of the atmosphere in a locality is diminished, an ascending current results. Currents of colder and heavier air rush in to supply the deficiency. The force and velocity of the currents thus created will be greater or less according to the difference of atmospheric pressure, or the "gradient," as meteorologists call this difference. The larger the gradient, the more violent will be the resulting wind.



Course of Cyclones

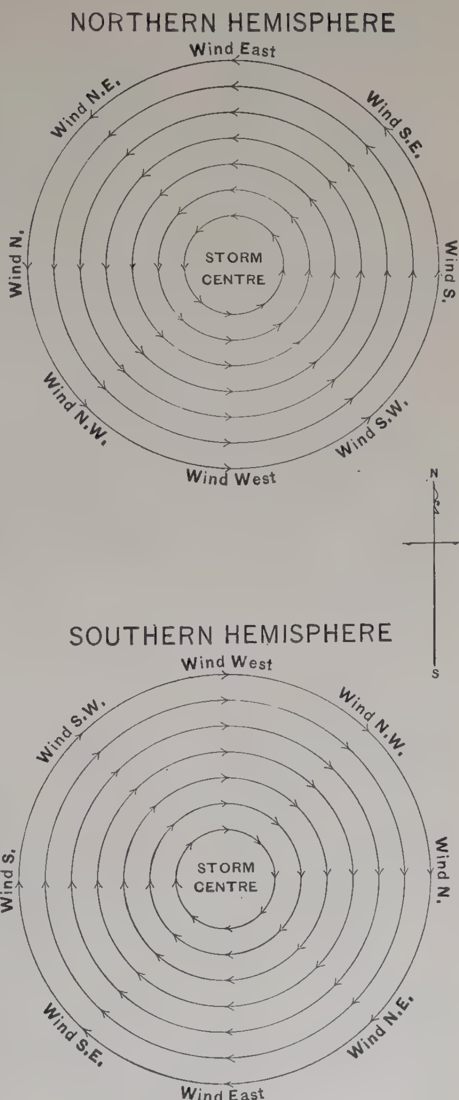
Suppose there is but one area of low barometer and one of high; the result will be a simple wind moving in one direction. If, however, the one area of low barometer is surrounded by areas of high barometer, it is evident that there will be an inflow of air from all directions. Such currents do not collide at the center, but, in obedience to

a force arising from the earth's rotation, are deflected to the right in the northern hemisphere and to the left in the southern.[1] They therefore circle round this area, thus forming a cyclone. The course of the atmospheric currents during a disturbance of this kind is shown in the diagram on p. 229.

Laws of Storms. — Cyclones obey the following laws:—

(1) The wind revolves in opposite directions according as the cyclone is in the northern or southern hemisphere. In the northern the direction of revolution is from right to left, or against the hands of a watch. In the southern it is from left to right, or with the hands of a watch.

As the wind constantly revolves, it constantly changes its direction at any given place in the storm track. On opposite sides of the center it has opposite directions. Hence it is easy to understand why



STORM CARDS

Showing direction of whirl in both hemispheres.

[1] Ferrel's law.

the wind changes as soon as the storm center passes. This is shown by the "storm cards."

The rate of revolution, or "velocity of the wind," is from 50 to 150 miles an hour.

(2) The storm, while revolving, has a progressive motion. The direction of this motion is determined by the prevailing winds. In general it is northwest and southwest within the zones of the trades, and northeast and southeast in those of the counter trades.

The course of tropical cyclones is well defined. North of the equator they move northwestwardly up to about latitude 30° N. Here they turn to the northeast. South of the equator they pursue the reverse course; starting near the tropics, they advance toward the southwest, and near the parallel or 27° they turn to the southeast. From this it will be seen that the pathway of cyclones somewhat resembles the curve called a *parabola*. (See diagram, p. 230.) The rate of travel varies from 1 to 70 miles an hour.

(3) The storm center is an area of calm and also of low barometer. The arrival of the storm center at any point is indicated by the barometer. The descent of the mercury in tropical storms often amounts to two inches. It is sometimes so rapid that it can be detected by the eye.

This fall of the barometer occurs at the storm center for two reasons: 1st, because the center is an area of warm, humid air; 2d, because the center is an area of rarefaction.

The air particles which are nearest the vertical center of the cyclone are apparently repelled outward from that center by their centrifugal force. This makes the air in the center less dense, or, as we commonly say, *rarefies* it. Under such conditions the barometric column sometimes falls as low as 27.5 inches.

Anti-cyclones. — Closely associated with cyclones are vast bodies of air the condition of which is the reverse of that of the cyclone. To such bodies of air is given the name *anti-cyclone;* that is, opposite of the cyclone.

The cyclone is warm, moist, and light. The anti-cyclone is

cold, dry, and heavy. Hence the area over which an anti-cyclone prevails is one of high barometer. Occasionally in an anti-cyclone the mercury will rise to 31.25 inches.

Again, while in a cyclone air currents flow inward from the circumference toward the center, in the anti-cyclone currents flow outward from the center toward the circumference.

Value of Storm Laws. — A knowledge of the laws of storms is of the utmost value to the navigator. By observing the direction of the wind he may learn in what direction the storm center is from him. The rule is: Turn your back to the wind and the low barometer is always to your left in the northern hemisphere, and in the southern hemisphere to your right. This will appear by examining the diagram on page 231, and imagining yourself with your back to the arrowheads. If the sailor knows where the storm center is, he can steer away from it.

Again, if he finds his barometer sinking rapidly, an inch or more below its usual height, he knows that he is in the storm center. Obviously it will be well to trim the sails and prepare for a gale. The center of calm will soon pass beyond and a tempest strike his ship.

The Areas of Storms differ in size and shape. In Europe they are nearly circular; in the United States, their shape is usually an elongated oval. They are seldom less than 600 miles in diameter. They average twice that amount.

Tornadoes and Whirlwinds differ from hurricanes and typhoons, (1) in duration; and (2) in extent of area.

In passing over any point, tornadoes seldom occupy more than a few seconds. Their breadth varies from a few yards to a mile or two, though their destructive effects are usually confined to a narrow path.

The rate of their progressive motion is commonly about 30 miles an hour, and the length of their course 25 or 30 miles.

An approaching tornado has the form of a funnel-shaped cloud pointing downward. A noise, perhaps due to electricity, and not unlike that of a train of cars, is heard; thunder, lightning, hail, and rain occur.

A partial vacuum is formed by the centrifugal force at the center. Sometimes when the end of the funnel dips down and touches a building, the vacuum resting over it so relieves the building from atmospheric pressure as to cause a sudden expansion of the air contained in it. The walls of the building then burst asunder as by explosive force.

A TORNADO

The tornado here shown is from a photograph taken by Mr. W. E. Seright at Stafford, Kansas, about 5:30 P.M., April 12, 1906. It was the last of six or seven similar manifestations which occurred within the radius of three or four miles the same afternoon. When photographed the cloud was probably a mile distant in a northeast direction.

Tornadoes sweep everything before them. Houses and other buildings are lifted up bodily, and lanes called "wind roads" are cut through the forests. Large trees are uprooted and whirled about like stubble.

The region of North America most frequently visited by tornadoes is the Mississippi Valley. During the past 50 years more than 600 have occurred there.

In the deserts of Asia and Africa, as well as in the region of the Great Basin of North America, whirlwinds sometimes draw up into their central core large quantities of sand and dust. They thus become moving columns of sand, 500 to 700 feet in height (as observed with sextant), and are known as "dust whirlwinds."

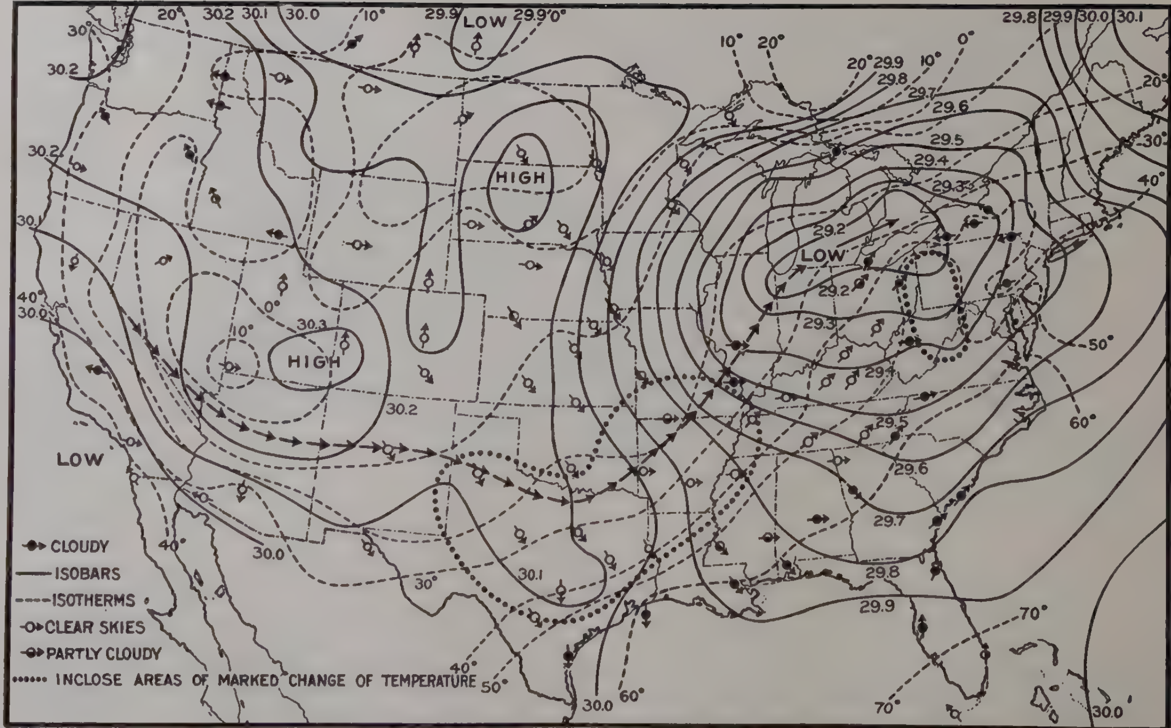
The *Simoom*, or "poison wind," appears to be a desert whirlwind intensely hot, and so rarefied as to be suffocating.

At sea, especially in certain parts of the ocean, waterspouts occur. These are tall moving columns of water. Scientific opinion is divided as to their cause. Some think that they are produced like the dust whirlwinds of the desert, by a revolving air current which draws up the spray of the waves into its core of low pressure. Others think that the water comes solely from the clouds. The cut seems to suggest the latter view. Two actual, careful observers of the spout photographed drew, however, opposite conclusions from their observations.

WATERSPOUT AS SEEN FROM OAK BLUFFS (COTTAGE CITY), MASS., AUGUST 19, 1896, AT 1:02 P.M.

Distribution of Storms.—The most violent storms occur in the vicinity of mountainous islands.

The Pacific is the most tranquil of the oceans. In those portions of its trade-wind regions where there are no islands, and where monsoons do not prevail, storms are almost unknown. The typhoons are confined to the southeast coasts of Asia and the East India Archipelago.



WEATHER MAP OF THE UNITED STATES

The South Atlantic, along the coast of intertropical Brazil, is almost stormless, whereas, in corresponding latitudes in the North Atlantic, among the West Indies, terrific hurricanes occur.

The portions of the Indian Ocean especially subject to hurricanes are the Bay of Bengal and the neighborhood of Mauritius.

Weather Forecasts.[1] — During the last 50 years observations upon the force and direction of the wind, the course and character of storms, the pressure of the atmosphere, the amount of rainfall, the temperature and moisture of the air, have disclosed certain general principles or laws of the weather.

Knowing these laws, and knowing by telegraphic reports the weather conditions prevailing throughout the country, it is possible to predict from day to day, with considerable accuracy, the approach of storms, or of cold or hot weather.

Most of the great storms of the United States travel in a northeasterly direction. They may be conveniently classed as those which come from the Pacific Ocean and those which come from the Atlantic.

The storms of the Pacific penetrate to a greater or less distance into the country, and often cross it entirely.

The storms from the Atlantic are first felt either at some southerly point on the Atlantic seaboard, or on the shores of the Gulf. Generally they come in from sea by the way of the Gulf, pass northward through the Mississippi Valley, and then turn to the northeast.

[1] Over 50 years ago Maury urged upon the attention of the government of the United States, and those of European nations, the desirability of having systematic meteorological observations carried on by all nations at sea. As the result of his efforts the United States government invited all the maritime states of Christendom to a conference, which took place in Brussels, 1853. The suggestions made were adopted. But the ideas of Maury were not limited to the ocean. In the preface to the second edition of his "Physical Geography of the Sea," published in 1855, he says: "It is a pity that the system of observations recommended by the conference should relate only to the sea. The plan should include the land also, and be universal." The present "U. S. Weather Bureau" with its well-organized Signal Service is the crowning result of his labors in this direction.

Those which make their appearance first on the Atlantic seaboard are the western halves of cyclones, which, pursuing their parabolic course, first northwestwardly and then northeastwardly, happen partially to embrace our shores within their area. These western half-cyclones consist of northeast and northwest gales. The eastern halves of the same storms, consisting of gales from the southwest and southeast, are at sea. The storm center pursues a course nearly coinciding with our shore line.

The transient and uncertain character of *tornadoes* renders it impossible to make exact predictions regarding them.

Ordinary storms, however, are so far regular that, in a large proportion of cases, their course, after they have once manifested themselves, may be foretold with some degree of accuracy.

The Weather Map. — The following description of the Weather Map is taken from a publication by the Chief of the United States Weather Bureau (see map, p. 236): "This map presents an outline of the United States and Canada, and shows stations where weather observations are taken daily at 8 A.M. and 8 P.M., seventy-fifth meridian time. These observations consist of readings of the barometer, thermometer (dry and wet), direction and velocity of the wind, state of weather, amount, kind, and direction of the clouds, and amount of rain or snow, and are telegraphed to Washington and to many of the Weather Bureau stations throughout the country for publication on maps and bulletins. Solid lines, called *isobars*, are drawn through points having the same atmospheric pressure; a separate line being drawn for each one tenth of an inch in the height of the barometer. Dotted lines, called *isotherms*, connecting places having the same temperature, are drawn for each 10 degrees of the thermometer. Heavy dotted lines, inclosing areas where a decided change of temperature has occurred within the last 24 hours, are sometimes added. The direction of the wind is indicated by an arrow flying with the wind, or opposite to the ordinary vane. The state of the weather — whether clear, partly cloudy, cloudy, raining, or snowing — is indicated by the circular symbol. Shaded areas, when used, show where rain or snow has fallen since the last observation."

XXII. MOISTURE OF THE AIR

Humidity. — More or less moisture is always present in the air. It exists as vapor. This vapor is invisible, yet its presence is often recognized by the sensation of dampness. The amount of vapor in the air is greater over the sea and other large bodies of water than over the land. It is dissipated by heat and condensed by cold. In arid regions the moisture available is less than the capacity of the air to hold, hence the air is dry. The presence or absence of moisture in the atmosphere has a marked effect on climate. Great humidity is enervating and not conducive to mental or physical exertion; temperature sensations are exaggerated; human activities curtailed. Dry air, on the contrary, is bracing, and higher temperatures can be endured without discomfort.

Evaporation. — One of the most remarkable properties of water is the readiness with which it passes from one of its states to another. Whenever it assumes the form of vapor it is said to *evaporate*, and the process of evaporation goes on at all temperatures and under all circumstances until the air is *saturated.* When the point of saturation has been reached, it can hold no more moisture.

You may have observed water drying in the streets and roads after a rain, or clothes hanging on the line frozen stiff, and yet becoming dry; or you may have seen a light fall of snow disappear in freezing weather. These were cases of evaporation.

Evaporation is accelerated and increased under the following conditions: —

(1) By high temperature. From this it follows that the maximum of evaporation is found within the tropics; the minimum at the poles. Furthermore, that evaporation takes place during the day, and in the warmest part of the day

(2) By diminution of pressure. In a vacuum there is almost no pressure, and there evaporation takes place almost instantaneously. Hence on the tops of high mountains, where the pressure of the atmosphere is very much diminished, evaporation goes on much more rapidly than it does at the sea level, where the full pressure of the entire atmosphere is felt.

Indeed, mountain peaks may be so high as to be entirely free from snow, while a belt of snow girdles the lower part of the mountain. The reason of this appears to be that at certain altitudes and under certain conditions snow evaporates so rapidly that it cannot accumulate.

Aconcagua in Argentina sometimes appears with its bare and bleak top peering above a girdle of snow.

(3) By a dry condition of the atmosphere. Warm dry air will absorb far more moisture than that which is cool and damp. If air be near the point of saturation, it is clear that evaporation will be retarded; but if the air be dry, it will be accelerated.

(4) By wind. If a wind blows upon the surface of water, evaporation is accelerated. As fast as one portion of the air becomes charged with vapor, it is removed, and a fresh portion takes its place.

Condensation and Precipitation. — Vapor returns to the liquid or solid state and is deposited upon the earth by the processes called condensation and precipitation.

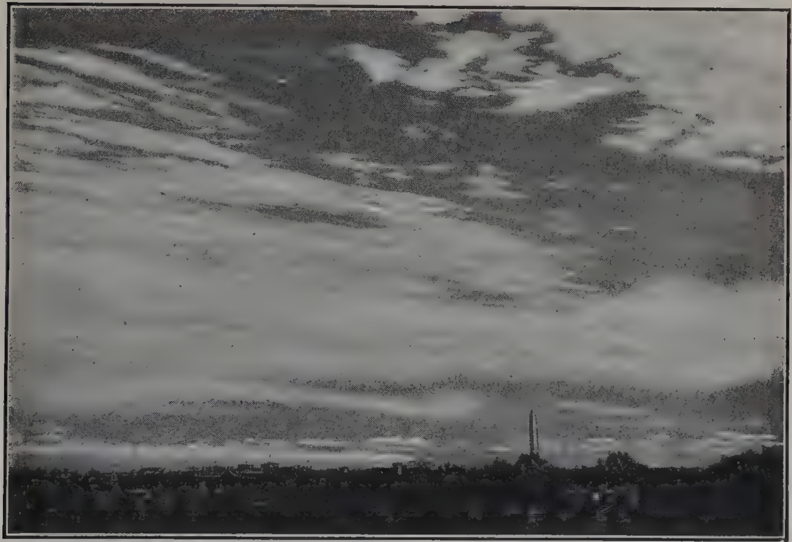
When condensed, it assumes the form of dew, white or hoar-frost, fog or cloud, hail or snow.

The great cause of precipitation, or the removal of moisture from the atmosphere, is loss of heat. The atmosphere can contain more or less vapor in a state of absorption in proportion to its temperature. If the temperature is 50°, a cubic foot of air can absorb about two grains' weight of vapor. At the temperature of 70°, that is, with an increase of only 20° of heat, the proportion of vapor is about twice as great.

From this it is easy to see why reduction of temperature causes precipitation. Suppose a cubic foot of air saturated with moisture to be reduced in temperature, even very slightly; it is ob-

vious that its capacity for moisture will be at once reduced, and a certain portion of its vapor must be precipitated. The temperature at which the deposit in such cases begins to take place is called the *dew-point.*

How Dew is Formed. — On clear and calm nights, the grass, the leaves, and other objects rapidly radiate their heat and grow



CIRRUS STREAMERS WITH LOW CUMULUS ON THE HORIZON, WASHINGTON, D.C.

From photograph by Professor A. J. Henry.

cool. They chill the surrounding air. It can no longer contain the same amount of moisture as when it was warm. Hence a portion of it is condensed and deposited upon the leaves in the shape of fine drops of water. We often say "the *dew begins to fall*," though, strictly speaking, it does not fall. It is deposited upon the grass precisely as, on a hot summer's day, the moisture is deposited on the outside of a pitcher of ice water.

Clouds check radiation, and hence on cloudy nights less dew, or perhaps none at all, is deposited.

You must have noticed that dew and hoar frost, which is mois-

ture condensed at a temperature below the freezing point, are deposited on some objects more copiously than others. This is because some radiate heat more rapidly, and therefore chill and condense more quickly the vapor that floats above them.

Fog. — Vapor coming in contact with cool air, if chilled below

CIRRUS CLOUD MERGING INTO CIRRO-STRATUS, WASHINGTON, D.C.
From photograph by Professor A. J. Henry.

the dew-point, assumes the form of fine watery particles which we call *mist* or *fog*.

It may also have been observed that in a clear, calm, and frosty morning the springs, ponds, and rivers "smoke." This phenomenon is identical with that exhibited by the steam which issues from the teakettle, the locomotive, and the steamboat. The "smoke" is a miniature fog.

Often, too, fogs are seen upon the surface of rivers in early morning, which vanish before noon. The morning air, being

cool, cannot absorb this moisture, but later in the day when its capacity has been increased by warming, it readily absorbs the fog.

The most foggy sea in the world is that part of the North Atlantic Ocean that lies on the polar side of latitude 40°; and the most foggy place is on the Grand Banks of Newfoundland.

DOUBLE-TURRETED CUMULUS, LOWER POTOMAC RIVER
From photograph by Professor A. J. Henry.

Vapor rises rapidly from the warm water of the Gulf Stream. Near the Grand Banks the Gulf Stream meets the icy Labrador Current. Owing to the chilling influence of this current, the vapor is condensed into fog as fast as it rises.

Though fogs are most frequent in summer, they occur on the Grand Banks at all seasons, producing in winter the exquisitely beautiful silver fogs of Newfoundland, which garnish the forests of that island with frostwork.

Clouds. — A cloud is simply a mass of mist or fog floating high in the air instead of near the ground.

Clouds present a very great variety of appearance, and hence are divided into seven classes: three simple, *cirrus*, *cumulus*, and *stratus*; four compound, *cirro-cumulus*, *cirro-stratus*, *cumulo-stratus*, and *cumulo-cirro-stratus* or *nimbus*.

The cirrus or curl cloud consists of white wavy lines or curled

CIRRO-CUMULUS CLOUD, "MACKEREL SKY," WASHINGTON, D.C.
From photograph by Professor A. J. Henry.

bands. It is the lightest of all cloud forms, and attains the highest elevations, floating four or five miles above the surface of the earth in regions of perpetual frost. It is supposed to consist of minute crystals of ice such as we see in the snowflake, and may be defined as frozen fog.

Cirrus clouds are often heralds of the cyclone. These nimble forerunners have been observed 800 miles in advance of a storm. They sometimes caution the mariner, before his barometer gives any intimation of the approaching tempest.

Cumulus clouds derive their name from the fact that they are heaped up, like vast mountains towering one upon another. They are often of glistening whiteness. They abound in the tropics, and frequently appear in the sky of temperate latitudes during the summer, when evaporation is rapid.

Of all cloud forms they are perhaps the grandest. Out of

CUMULO-STRATUS, KNOXVILLE, TENN.

them darts the lightning which makes our thunder storms so magnificent.

Stratus clouds appear in the shape of long layers or ribbons. They are seen most frequently in the evening, and, when tinged by the rays of the setting sun, they form those islets of gold which render the sunset sky so beautiful.

The compound clouds combine the features of the simple ones from which they are named.

The Cirro-cumulus is made up of fleecy masses of cirrus which roll themselves up into rounded shapes. These cause the mottled appearance commonly known as a "mackerel sky."

The Cirro-stratus consists of layers of cirrus clouds. They are often so arranged as to resemble a shoal of fishes, all swimming parallel to one another. This cloud, like the cirrus, is often the precursor of storms.

The Cumulo-stratus is formed of heaped clouds resting on layer clouds. Like the cumulus, its general mass is often quite

CUMULUS AND NIMBUS, SEASCAPE
(United States Weather Bureau.)

dark and threatening, while its edges are bright with sunshine that is behind the clouds.

The Nimbus is simply a cloud of any kind from which rain falls. Heaped clouds, and curls and layers blend together, lose their characteristic features, and form one dense leaden mass. It often overspreads the whole heavens.

When clouds rest on the tops of mountains, they are actually in contact with the earth; often indeed they are below the summit of the mountain. Their average elevation, however, is about half a mile. At times they cannot be less than four or five miles high.

The velocity of cloud movement, when accurately estimated by observers, is found to be far more rapid than we should suppose from the apparent rate of the "passing cloud." It has been found that cirro-cumulus and cirrus clouds which seem to be moving at a leisurely rate are often traveling 75 to 100 miles an hour.

This is of very great interest, for it indicates to us the velocity of the upper currents of the atmosphere.

Clouds screen the earth from excessive heat in summer, while as a mantle they keep it warm in winter by checking radiation.

Plants and animals are distressed by the intense heat of the noonday sun. But the more powerful the ray, the more rapid is evaporation. Soon vapor enough is lifted from the earth to form the mitigating clouds. They overshadow the land, and plants and animals rejoice in their shelter.

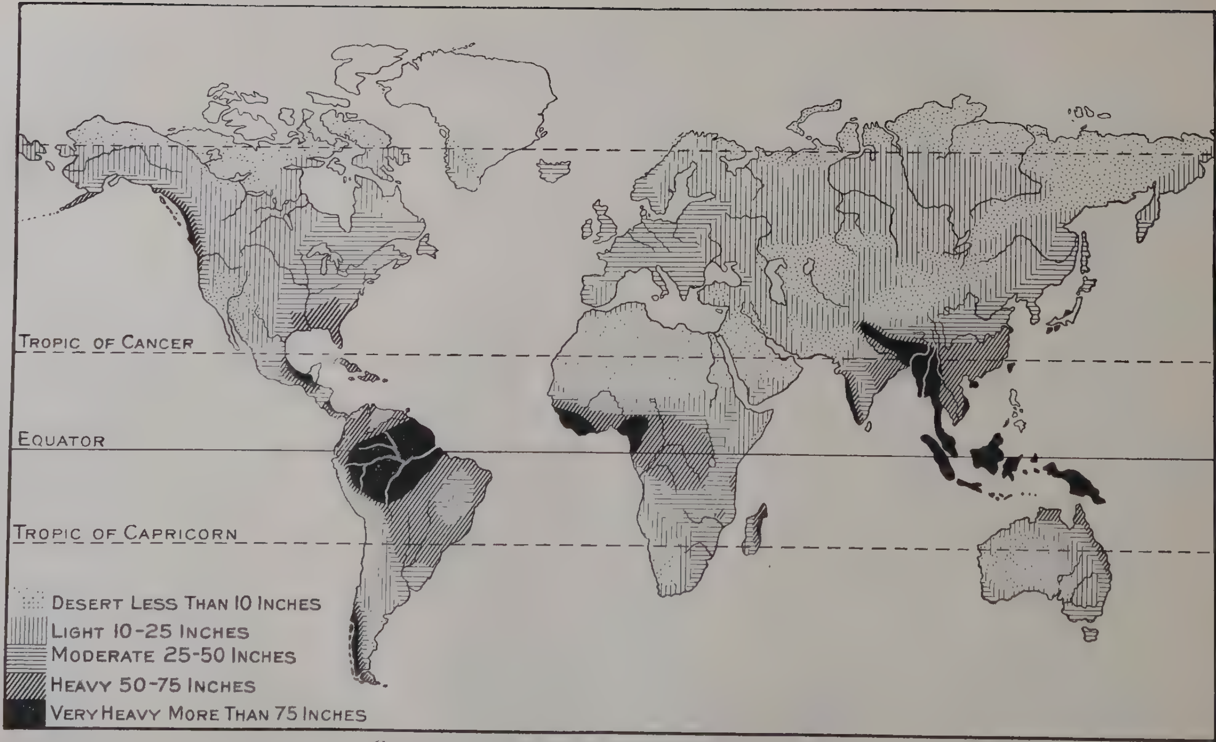


Chart showing the Distribution of Rainfall
(Mean Annual Precipitation.)

XXIII. RAIN

General Statement. — The first form assumed by the moisture of the upper air when condensed is that of cloud. If, however, the process of condensation continues, and vapor exists in abundance, it is easy to see that the tiny water particles which make up the cloud will increase in size, until they are too heavy to float, and will fall as raindrops to the earth.

The general cause of rainfall is that a certain volume of vapor-laden air has been chilled below the dew-point, so that it has no longer the same capacity for moisture as before. This may be brought about in several ways: (1) The moist air may be driven against lofty mountain slopes and cooled by contact; (2) it may be chilled by being mixed with a mass of colder air; (3) it may be chilled by expansion, as when carried upward by ascending currents of heated air, wafted over high mountains, or drawn into the center of a cyclone. Expansion has the effect of cooling air and condensing its vapor. This last cause produces the heaviest rainfalls for short periods.

Distribution of Rain. — Rain is very unequally distributed over the earth.

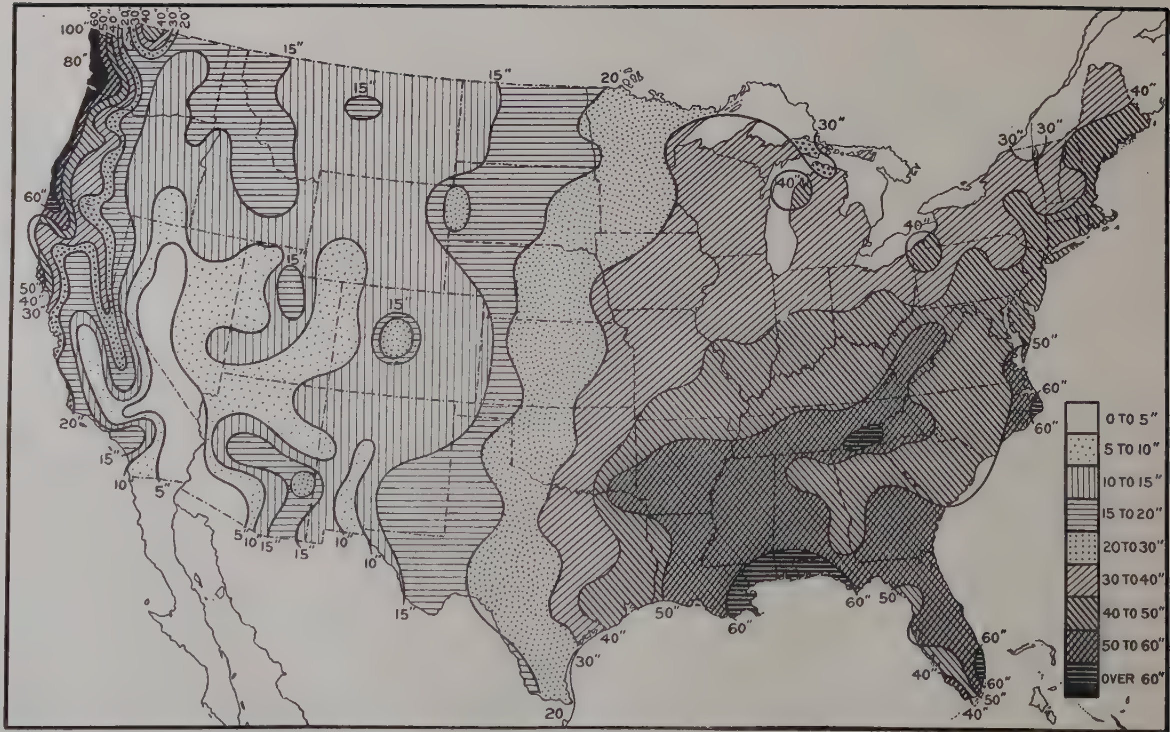
(1) The rainfall is greater on land than at sea.

(2) It is greater in mountainous than in level regions.

(3) It is greater in the torrid than in any other zone.

The average annual quantity at the equator is eight feet. It diminishes, however, on either side as we approach the poles. This follows from the fact that the torrid zone, being the hottest, is that of the greatest evaporation.

Dry air cools about 1° for each 183 feet of ascent; but if moisture is present, as soon as condensation takes place, the latent heat set free reduces the rate of cooling.



RAINFALL IN THE UNITED STATES
(Mean Annual Precipitation.)

These are the general facts regarding the distribution of rain. We must now consider more in detail how this distribution is brought about.

Regulators of Rainfall. — The great regulators of rainfall are mountains, deserts, and winds. Each of these has an important part to perform in the distribution of rain over the surface of the earth.

Mountains are the great condensers of vapor. If mountain chains face winds coming from the sea, the land lying between them and the sea is well watered. As they rob the winds of their moisture, not unfrequently the region lying beyond them is rainless.

Thus the Himalayas face the southwest monsoon, as it comes freighted with vapor from the Indian Ocean. They make India one of the most productive countries in the world; but the plateaus lying to the north of them are almost rainless. On a smaller scale the Western Ghats act in the same way. They, too, lie in the pathway of the monsoons, and intercept and condense their vapors. The annual rainfall upon their tops amounts to about 260 inches, while the country on the east of them receives less than 30 inches.

But perhaps the most striking illustration of the influence of mountains upon rainfall is to be found in the case of the Khasia hills, on the northern shores of the Bay of Bengal. They intercept the southwest monsoons as they come burdened with vapor from the bay. The result is that the winds, as they slant up the hills into the higher and cooler air, have their moisture at once precipitated as rain, of which about 500 inches fall there in the year.

In South America the influence of the Andes is familiar. The northeast and southeast trades come from the sea saturated with vapor, and so go into the interior, rising, and cooling, and dispensing showers as they go, until they reach the crest of the Andes. Here the cold and expansion are sufficient to precipitate almost all the remaining moisture. Thus the eastern side of these mountains, within the trade-wind region (see Chart of

the Winds), is abundantly watered, while the western is dry. Hence it is that Peru is a rainless country.

South of the mouth of the Plata, the reverse takes place. There the prevailing winds are from the west. They come from the Pacific, reeking with moisture, and water the western slopes of the Andes, causing the excessive rains of southern Chile, while the eastern slopes are comparatively dry.

In our own country the Cascade Range and the Sierra Nevada have a similar influence. They lie in the pathway of the westerly winds which come loaded with moisture from the Pacific. They act as condensers, and bring down the copious showers which give fertility to the Pacific slope.

In mountainless areas, like the Dakotas, rain and snow are caused by currents of cold air descending from the upper regions of the atmosphere. They reduce the temperature with surprising rapidity. Pouring into a warm atmosphere, they condense its moisture, and a rainfall or snowfall is the result.

In many cases deserts are the directors of the winds, and thus become regulators of the rainfall.

India is in a region in which the northeast trade winds blow over the land and are rainless. Were it not for the deserts of central Asia, which have the effect of drawing in the southwest monsoons (see p. 224), India would be as arid as Gobi.

In Africa the Sahara produces the monsoons which blow from the Indian Ocean upon that continent. By June, the desert is heated sufficiently to bring in the sea winds. The rainy season then begins, and lasts till late in autumn.

The periodical overflow of the Nile is due to rain resulting from the condensation of vapor brought from the sea by the African monsoon. Thus Egypt owes its fertility in some degree to the burning sands of the Sahara.

North America has its deserts and its monsoons, though they are far less marked than those of the Old World.

The table-lands of Mexico, Arizona, the dry plains of Texas, New Mexico, and the neighboring regions, are heated by the summer sun to such a degree, that the air resting upon them becomes rarefied, and ascends, the cooler air

from far and near coming in to restore the equilibrium. Thus a southeast monsoon is created in the Gulf of Mexico, and a southwest one in the Pacific.

Both of these winds blow toward the land, and bring the rains to Mexico, so that one side of that country is watered from the Pacific, and the other from the Atlantic Ocean.

As a general rule winds are dry, if they have traversed the land or if they are journeying toward the equator. Winds are wet, if they have traversed the sea or if they are journeying from the equator.

Land winds are dry for the simple reason that they have so little opportunity to take up moisture. Thus the northeast monsoons which sweep over the inland regions of Asia are the dry monsoons. The westerly winds of our own country, from the Sierra Nevada to the Atlantic, are dry winds. They bring our fair weather.

Again, a wind that is blowing toward the equator is dry, because, entering warmer latitudes, it is gaining capacity for moisture with every degree of its progress. The trade winds, for example, blow toward the equator. You perceive, therefore, that they are going from cooler to warmer latitudes. Their temperature is increased by the way, and with increase of temperature there is increase of capacity for moisture. The trade winds, therefore, take up more water from the sea than they return to it. They are evaporating winds.

Sea winds and winds blowing toward the poles are rainy. The counter trades go toward the poles. They are traveling from warmer to cooler latitudes. Their temperature is decreased by the way, and therefore there is a decrease in their capacity for moisture; they deposit more than they take up. They are, therefore, rain winds.

Rains Classified. — The winds are classified according to the regularity with which they blow, as constant, variable, and periodical. It is proper, therefore, to classify the rains which they bring in the same way. Hence, according to the nature of the supplying winds, the rainfall in any given region is *constant*, *periodical*, or *variable*.

The constant rains are confined to a belt near the equator, about 5° wide. In this belt there are almost daily showers. The cause is clear. The northeast and southeast trades meet near the equator. They are so completely saturated with moisture that the sailor hanging out his clothes in the morning, is often surprised to find in the evening that they have not dried in the least. Under the vertical rays of the sun an ascending current is produced which carries the vapor-laden air into the higher regions of the atmosphere. Here the vapor is cooled and condensed; and hence the frequent thunder showers of this region of constant precipitation.

Within the tropics, to the north and to the south of the narrow belt of Constant Rains, lie the zones of Periodical Rains.

In the New World the periodical rainfall is closely connected with the annual movement of the Equatorial Calm Belt and its accompanying Cloud Ring.

The Calm Belt travels northward and southward, following the apparent annual movement of the sun in the heavens. It is farthest south in March, and farthest north in September.

During the time that it is passing over a place, it gives to that place its rainy season. After it has passed, there is scarcely a drop of rain until it comes again.

Let us follow the Cloud Ring in its journey from south to north, and we shall readily understand its movements, and the rainy seasons that depend upon them.

The time is February; it is then over Guayaquil (Lat. 3° S.), and then the rainy season there is at its height. It commences its movement for the north in March. Quitting the skies of Guayaquil soon after, it leaves them bright and clear with the commencement of the dry season. In a little while it has traveled as far as latitude 4° N. It then overshadows Bogotá, where the rains begin in April or May. In June it is over Panama, and hence a rainy season prevails there: and so the Cloud Ring continues on to Mexico, reaching Mazatlan, just under the tropic, about September, when it commences its march toward the south, so as to be again at Guayaquil by February or March.

It is clear that on its return from north to south the Cloud Ring must give

to certain places a second rainy season because, in coming and going, it passes over them twice.

In the Old World the periodical rains are occasioned by the monsoons or reversed trades. For about six months, in southern Asia and central Africa, copious rains fall. When the monsoons change, the dry season sets in, and scarcely any rain falls until after six months, when the wet monsoon begins to blow again.

Within the two belts of Periodical Rains the year is divided into rainy seasons and dry.

In general terms, the rainy season in the northern belt may be said to begin with April and last till October, while the dry season extends from October till April. In the southern belt this order is reversed — the dry season lasting from April till October, and the season of rain from October till April.

It is not to be supposed that during the rainy season there is an incessant fall of rain. In Mexico, for instance, the rainy season is the most delightful portion of the year. As a rule the nights and mornings are clear and beautiful, and the weather fine, with a few hours of rain after three or four o'clock P.M.

North and south of the belts of Periodical Rains, the rains become variable; that is, they are irregularly distributed through the year. In some countries they occur mainly during the summer, in others during the winter; in others, again, during the spring and autumn. This condition prevails throughout the temperate regions.

Excessive and Deficient Rainfall. — Owing to the influence of local causes, there are regions of excessive and deficient rainfall.

The regions of excessive rainfall, with few exceptions, lie within or near the tropics. Cherrapunjee, in the vicinity of the Khasia hills in India, receives annually about 500, and in some years 600, inches — or a depth of 50 feet — a greater amount, so far as we know, than any other place on the globe.

Parts of the British Isles, the coasts of Guinea and Senegambia, eastern Africa and India, are all remarkable for their heavy rainfall.

In the New World, Brazil, Guiana, Venezuela, the West India Islands, Central America, southern Chile, and the Pacific shores of Alaska are all regions of excessive rainfall.

The Primitive Method of Irrigation practiced by the Egyptian Peasants

The water is raised in vessels attached to "sweeps" with counter weights at the opposite ends.

The rainless or almost rainless regions are the great belt of deserts extending across Africa and Asia, from the Atlantic nearly to the Pacific; the Great Basin in North America, lying eastward of the Sierra Nevada; Peru, together with the northern part of Chile, portions of Argentina lying eastward of the Andes, and the interior of Australia.

Cultivation in all dry countries is carried on by means of irrigation. For this purpose tanks have been constructed in India at vast expense. The Peruvian farmers avail themselves of the mountain streams that are fed by the snows of the Andes; while the peasant of Egypt, like his forefathers, supplies his fields and gardens from the waters of the Nile. (For irrigation in United States, see p. 320.)

XXIV. HAIL, SNOW, AND GLACIERS

Hail. — Moisture, descending through the cold upper regions of the atmosphere, is sometimes frozen and becomes hail or snow.

When examined carefully, hail has been often found to consist of concentric layers of ice, incasing one another like the layers of an onion.

In size, hailstones vary. At times they are as large as marbles, or even hens' eggs, so that severe hailstorms may occasion very great damage to crops.

The formation of hail is not well understood. The sudden ascent of moist air into the cold upper regions of the atmosphere is probably the most common cause of this phenomenon.

Glaisher, in his balloon ascension, found the temperature, at the height of three miles, 18° F.; at four, 8°; at five, −2°. The temperature at the surface was 59°.

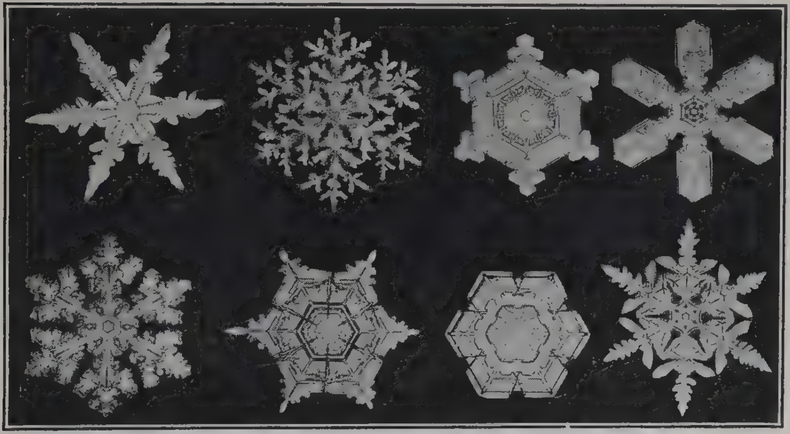
Snow. — The moisture that falls from the clouds, frozen in flakes, is called snow. When examined, it is usually found to consist of exquisitely formed crystals, which are generally in the shape of a six-pointed star. (See illustration.)

Snow rarely occurs within the limits of about 30° north and south latitude, except on high mountain tops. It is naturally more abundant as we approach the poles. It is also in general more abundant where the climate is inland, than where it is maritime. Paris has, on an average, 12 snowy days in the year; St. Petersburg, 170.

Snow is perpetual, however, even at the equator, upon all heights greater than about three miles above the sea level. The line above which snow is always found is called the *snow line*. It varies in altitude from many causes.

Whatever tends to elevate the temperature of any locality tends also to elevate the snow line. Hence a low snow line means a cold climate. While at the equator the snow line is 16,000 feet high, at the Straits of Magellan it is only about 4000, and in Norway about 5000.

The use of snow is twofold: (1) it protects the earth and the crops planted in late autumn from the intense cold and the injurious effects of frost. Sometimes there is a difference of 40° between the temperature of the ground a little below the surface and that of the snow that covers it; (2) falling in vast



SNOW CRYSTALS

quantities on the great mountain ranges, as the Himalayas, the Alps, and the Rocky Mountains, it serves as a perpetual feeder of the rivers.

The quantity of snow that falls on an extensive range of mountains, such as the Alps, is very great. Agassiz observed a fall of 57 feet in six months at the Hospice of Grimsel, and observations during twelve years near the Pass of the Great Saint Bernard showed an annual snowfall varying from 12 to 44 feet. It has been estimated that the average annual snowfall on the Alps amounts to 60 feet, which is equivalent to six feet of water.

A large part of the snow, as already stated, gradually melts and flows

through the river courses to the sea. Other, though smaller portions, consolidated into ice, descend the mountain slopes into the valleys as glaciers. Frequently masses of snow are loosened from their beds and plunge down the steep declivities with frightful velocity, forming avalanches. Sometimes the echo of a loud word is enough to disturb an overhanging mass and hurl it into the valley below.

EFFECTS OF AN AVALANCHE
A scene in the Selkirk Mountains of British Columbia.

Many instances are on record of the appalling destruction wrought by this scourge of the Alps, whole villages having been overwhelmed and hundreds of lives destroyed by a single avalanche. Thick forests are the best protection against danger from this source, and in former times the penalty of death has been adjudged against any who should destroy a single tree of the protecting barrier.

Glaciers are vast masses of ice either spreading out over the surface, as in Greenland and the Antarctic regions, or filling valleys, as in the Alps and other snow-clad mountains.

A SNOW-CLAD SUMMIT — MONT BLANC, "THE MONARCH OF THE ALPS"

This mountain has an altitude of 15,730 feet. In the foreground is seen the village of Chamounix. Note the glacier extending downward into the valley.

In regions where the snowfall exceeds the loss by melting, the accumulated snow gradually becomes compacted by partial melting and by the pressure of its own weight. Moreover, that which occupies the higher levels gradually creeps downward to the lower — to the edge of the plateau in the case of an ice sheet, or down a valley in the case of a mountain glacier.

Should we follow a ravine downward from a snow-clad crest, we should find the snow growing more and more solid under our feet until we reached the snow line. Below this the compacted snow would appear as ice. Following the ravine to a still lower level, we should observe that the ice mass filled it from side to side and terminated at length among gardens and pastures, a stream of water gushing from its cavernous extremity.

Other glaciers, smaller in extent, and containing comparatively little ice, never reach the lower valleys.

MER DE GLACE — SEA OF ICE

This celebrated glacier is formed by the union of several branches descending from the Mont Blanc range.

The compacted snow above the snow line is called the *névé* (nā-vā). It is in general about half the density of ice, or more than three times that of snow.

Glacial Motion. — Solid and immovable as these mighty masses of ice appear, they are really in motion. Long before glacial motion was suspected by scientific men, it had been known to the mountaineers that blocks of stone lying upon the surface of glaciers moved slowly downward.

A large number of carefully conducted observations have

been made, which prove not only that the glacier has motion, but that its motion closely resembles that of a river. It is swiftest in the center, and slower, owing to the friction, near the sides and bottom. Notwithstanding this movement, the termination of the glacier retains about the same position from year to year, because it is melted away as fast as it moves downward.

Franz Josef Glacier, New Zealand

This glacier lies on the western slope of the Southern Alps. Its length is 8½ miles.

The rapidity of the motion of a glacier depends upon the season of the year, the size of the glacier, and the inclination of its bed. The motion is more rapid in summer than in winter, in the daytime than at night, and in a large and deep glacier than in a small one.

The average rate per year for glaciers of the Alps varies from 25 to about 100 yards.

The middle of the Mer de Glace was found by Tyndall to

move 20 to 33 inches a day in summer. The rate is about half as much in winter.

The following figures express in yards the motion, during one year, of a row of poles set in a straight line across the glacier of the Aar, by Professor Agassiz: —

5. 20. 48. 55. 62. 64. 67. 69. 79. 68. 64. 54. 47. 39. 21. 11. 1.

The central part, therefore, moved about 80 yards a year.

The great glaciers of Greenland and Alaska move at various rates, 60 or more feet a day.

Some glaciers, notably that of the Rhone, tell their own tale of their movement down the valley. On their surface concen-

THE MUIR GLACIER, ALASKA

This great ice-stream, which results from the union of many tributaries, enters an inlet of the sea. Its water front is about a mile wide and rises perpendicularly 250 feet or more. From it masses of ice break away which float off as small icebergs. Since the above photograph was taken the extremity of the glacier is less accessible to tourists on account of the shoaling of the inlet.

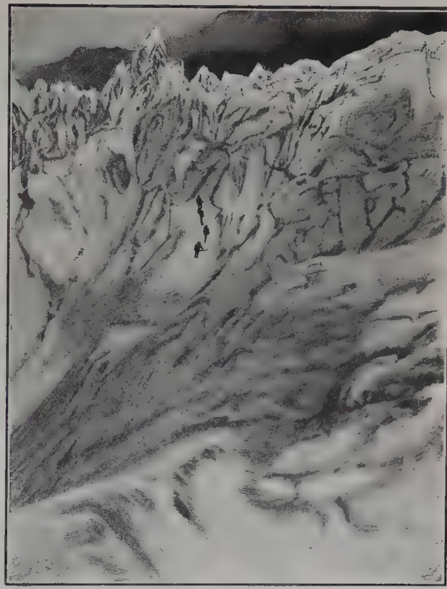
tric curves are seen bulging toward the lower end of the glacier. These show, as clearly as a line of stakes, the more rapid movement of the central portion of the glacier.

Owing to the slowness of glacier motion, it may be a century or more before what is now the upper end of the glacier will get to the foot of the mountain.

Theory of Glacial Motion. — Various theories, none of which is in all respects satisfactory, have been advanced to account

for glacial motion and the accompanying phenomena. The first thing to be accounted for is the motion itself. Two causes for this may be given: (1) gravitation; (2) expansion within the glacier. It is probable that both these take part in producing the motion.

Gravitation, or the weight of the glacier, would naturally draw the mass down the slopes of the valley.



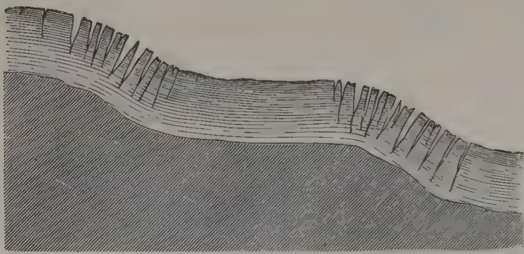
CROSSING FRANZ JOSEF GLACIER, NEW ZEALAND
Note the irregularities of the surface in the form of pinnacles which have resulted from superficial melting.

Expansion within the glacier needs explanation. When the water from the melted surface of the glacier percolates downward into the interior of the mass, it encounters a temperature of 32° F. It freezes and of course expands. Its expansion must take place in the direction of least resistance, which, owing to gravity, is toward the lower end of the valley.

The following facts must now be considered: first, that the ice of a glacier accommodates itself to the shape of its inclosing valley very much as a river does to its channel; and, second, that after fracture its parts reunite. These phenomena are explained by what is known as *regelation* or *second freezing*. If we pound a mass of ice into fragments and then moisten the broken surfaces, the fragments will readily freeze compactly together again.

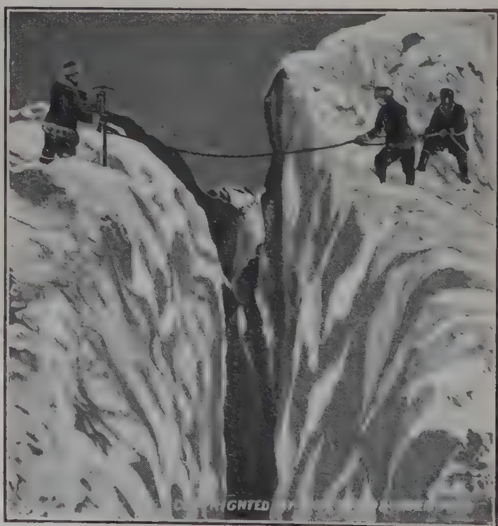
This is what occurs in a glacier. In passing through narrow gorges it is crushed and broken, and in gliding over steep

irregularities in its bed it is cracked and splintered. The lower parts break away from the upper, and fissures of great depth called *crevasses* are formed, as shown in the following illustration.



CREVASSES

But after the ice has been thus broken and splintered or sundered by crevasses, it reunites and forms one compact mass. The crevasses admit warm air, and their walls are perhaps slightly thawed, or the ice on the top of the glacier being melted, water trickles down and moistens the fractured surfaces. In this condition, the mass of fragments is compressed by its confining valley walls, the sundered portions are brought together again, and regelation occurs.



A CREVASSE

This fissure was encountered in making an ascent of the Jungfrau, Switzerland. From stereograph. Used by permission.

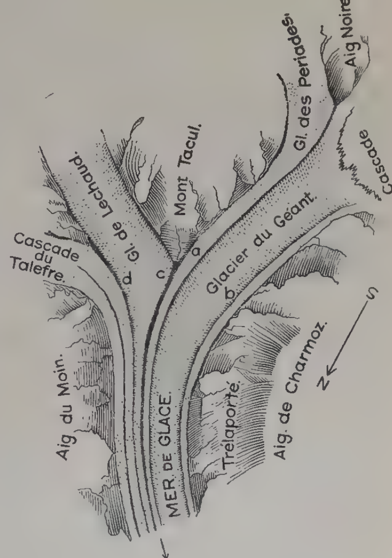
Under pressure ice melts at a lower temperature than 32° F. If a wire weighted at each end is caused to cut through a block of ice, water will be seen flowing round the wire, while, in the cut behind or above the wire, it is found to be frozen. This experiment has an important bearing upon the phenomena of glacier motion. Pressure is obviously exerted by certain portions of the

glacier upon others, especially when the glacier is squeezed within gorges. If this pressure reduces the melting point from 32° F. to 28°, the mass being above the latter temperature, it is easy to see how the onward movement of the glacier would be facilitated by reason of its partial liquefaction.

Moraines. — The rocks and débris brought down from the slopes of the ravine by the action of the frost and by avalanches accumulate on the sides of the glacier, forming dark bands of earth and stones, varying in size according to the character of the rock encountered. These bands are called *moraines*. Occurring at the sides they are called *lateral moraines*.

At the confluence of two glaciers, the moraines which skirt the two sides that join are united, and form a *medial moraine*. If another glacier unites with this again, a second medial moraine is formed in the same manner.

The earth, stone, and bowlders brought down on the glaciers form, at the lower end of the glacier, where the ice melts and leaves them, immense deposits called *terminal moraines*.



MORAINES (*a*, *b*, *c*, *d*, *e*) OF THE MER DE GLACE

In the above cut it will be seen that the Glacier du Géant unites first with the Glacier des Périades, and from their junction the dotted line shows the medial moraine formed from the right moraine of the Géant glacier and the left moraine of the Périades. Where the glacier thus reinforced receives the Glacier de Léchaud, another medial moraine is formed; and a third where the Taléfre adds its tributary stream. By the junction of these is formed the Mer de Glace.

Bowlders of Transportation. — In some regions of the earth the surface is strewn with bowlders derived from distant sources. They evidently once formed a part of an old moraine, and their

presence is explained by the transporting power of glaciers. As the ice melted they were deposited in their present positions and sometimes so gently as to form the so-called rocking stones that may be swayed back and forth if pushed by the hand. These transported bowlders vary greatly in size. They may weigh hundreds of tons, but usually they diminish in size as the

A Transported Glacial Bowlder, Yellowstone National Park

This massive bowlder of granite is 24 feet long, 20 feet wide, and 18 feet high. To have reached its present position, near Inspiration Point, it must have been carried from 30 to 40 miles.

distance from their origin increases. A belt of country extending from the Baltic to the Black Sea is strewn with bowlders rent from the Scandinavian mountains.

The Glacial Period. — The former existence of extensive ice sheets over the northern portions of Europe and North America is evident. Among the proofs may be cited the following: the occurrence of smooth and polished rock surfaces; striations and

grooves similar to those found in regions known to have been glaciated; old moraines; transported soils and bowlders; valleys filled with transported rock waste; ice-eroded rock basins now forming lakes.

The time of this ice invasion in the earth's history dates from an age just preceding the probable advent of man. So extensive were the alterations of surface features then produced that sufficient time has not yet elapsed to obliterate the evidence.

MAP SHOWING THE AREA OF NORTH AMERICA COVERED BY ICE IN THE GLACIAL PERIOD

Salisbury. Geological Survey of New Jersey.

Drumlins, Eskers, and Kames. — In certain glaciated areas, as in central New York, central and eastern Massachusetts, and southern Wisconsin, there are found hills and ridges of glacial débris or *till* having an oval or elongated oval form and smooth, rounded surfaces. Their longer axes lie in the direction of the ice movement, as will appear from an examination of the striæ and grooves on the neighboring rocks. Such elevations have been termed *drumlins*. Their height varies, but rarely exceeds 100 to 200 feet; their length also varies, ranging from a half a mile in the short forms up to a mile or even two miles in the more elongated forms. These hills are of a morainic character and often constitute the most prominent features of a landscape.

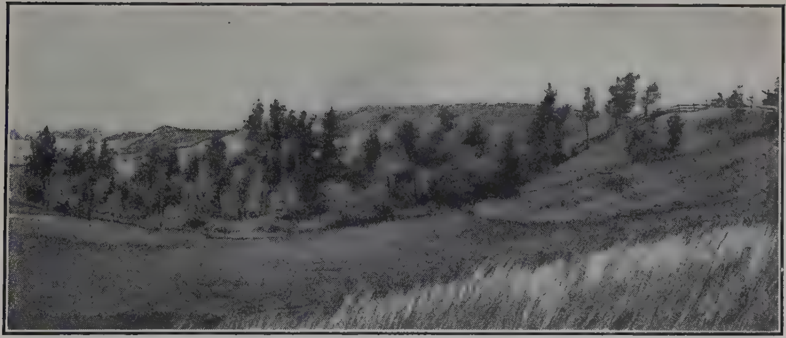
Glacial Grooves at Kingston, Iowa — Iowa Geological Survey
In these groovings the movement of the ice body in four directions is recorded.

Another topographic feature of glacial origin is seen in the winding or sinuous deposits of washed sand and gravel which

Drumlin, Savannah, Wayne County, New York
The right-hand end has been notched by the wave cutting of Lake Iroquois, the predecessor of Lake Ontario. From photograph by Professor H. L. Fairchild.

form well-defined ridges, not often exceeding 50 feet in height and usually of less elevation. They are known as *eskers*. Their origin is somewhat obscure, but it is thought that they represent deposits of débris in subglacial streams flowing in tunnels or deposits in canyonlike gorges cut in the ice by stream wear and melting.

Closely related to drumlins and eskers are mounds or knolls of sand and gravel, glacial débris, which has been more or less stratified through water action. These deposits have been termed *kames*. The materials of which they are composed were evidently deposited adjoining the ice by streams issuing



SIDE VIEW OF ESKER, PITTSFORD, NEW YORK

From photograph by Professor H. L. Fairchild.

from glaciers and, whenever the ice melted, left in the form of mounds.

Glaciers as River Sources. — The glacier, as it imperceptibly glides down the mountain, is melting all the time, and the traveler upon its rugged surface may hear, far down in its creviced depths, the sound of running water, which gathers volume from a thousand trickling streamlets, and at last issues forth, the never failing source of some noble river.

The Rhine, the Rhone, and many tributaries of the Danube and Po spring from glaciers in the region around the Saint

Gothard; and every one of the hundreds of glaciers found among the Alps nourishes some stream. The Ganges, in India, leaps out from under a glacier, a torrent 40 yards in width.

Distribution and Size of Glaciers. — Glaciers of enormous size are found in the Arctic and Antarctic regions. In the Old World the grandest glacier region of the Temperate Zone is that of the Himalayas. The glacier of Bépho, in one of the

A GROUP OF KAMES, MENDON PONDS, MONROE COUNTY, NEW YORK

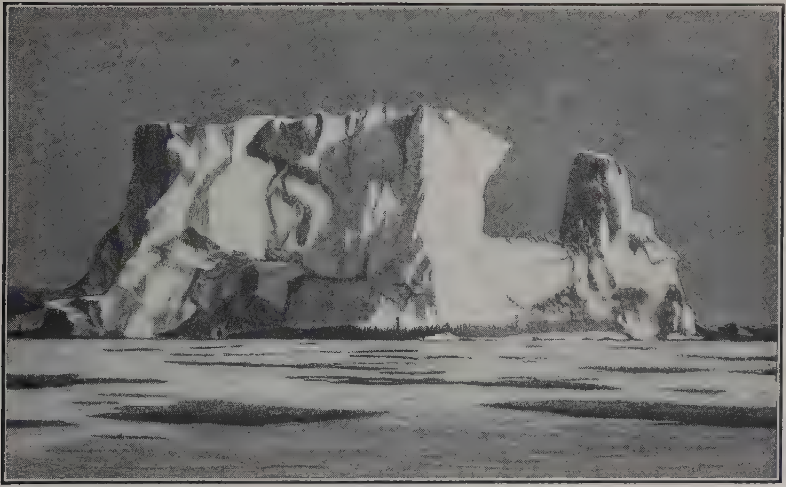
From photograph by Professor H. L. Fairchild.

valleys of the Karakoram range, is 36 miles in length — about four times as long as the Mer de Glace — and covers hundreds of square miles in area. Many others in the same region are of nearly equal extent.

It is estimated that the number of large glaciers in the Alps is about 500, and that the surface constantly covered by snow, névé, and ice is more than 1000 square miles. The thickness of the Alpine glaciers is believed to range from 200 to 800 feet.

The Pyrenees and the Scandinavian mountains contain glaciers, and large ones exist in the Caucasus.

In the New World, Greenland and Alaska have glaciers far surpassing in magnitude those of the Old World. The Humboldt Glacier, in Greenland, is more than 60 miles in breadth and 300 feet deep. The Malaspina Glacier of Alaska, according to Russell, has an area approximating 1500 square miles. He has described it as "a vast, nearly horizontal plateau of ice."



An Iceberg

Glaciers are also found upon Mount Shasta, upon Mount Rainier, and in the Selkirk Range in Canada. The Andes, except at their southern extremity, are destitute of them.

As distinguished from *valley* glaciers, *continental* glaciers or ice sheets cover the entire surface over large areas. They are great snow and ice plains or, if sufficiently elevated, plateaus. At present they occur in Greenland and the Antarctic regions. The ice sheets of the Glacial Period were undoubtedly of this type.

Icebergs. — The glaciers of the polar regions are not melted into rivers like those of temperate latitudes. Their lower ex-

tremity, therefore, is pushed out into the sea, and masses, often of great size, are broken off from time to time by the buoyancy of the water and borne away by ocean currents. These are called *icebergs*.

On the polar side of 55°, south, the sea, all the way round the earth, is studded more or less thickly with icebergs.

During his Antarctic voyage in 1841, Sir James Ross sailed 450 miles along an unbroken barrier of ice. It stood 180 feet out of the water, and was aground in water 1500 feet deep.

Admiral D'Urville fell in with an ice mass off the Cape of Good Hope 13 miles long and 100 feet high. Maury met with them as near the equator as 37° south latitude. Indeed, icebergs come from the unexplored Antarctic regions in sufficient number to stud an area as large as the continent of Asia; for navigation is endangered there by ice throughout an area of not less than 15,000,000 square miles.

On the north side of the equator icebergs are found only in the Atlantic; never in the Pacific Ocean. They drift out from their nurseries in the polar regions with the cold currents, which bear them southwardly until they disappear in the warm waters of the Gulf Stream. They frequently lodge on the Banks of Newfoundland, where they greatly imperil navigation.

XXV. ELECTRICAL AND OPTICAL PHENOMENA

Atmospheric Electricity. — Concerning the precise nature of electricity we are ignorant. Although known only by its manifestations or effects, it has been defined as a "powerful physical agent." Among the phenomena attributed to it are shocks more or less violent, heating and luminosity, chemical action, attraction and repulsion, etc. Electricity is of two kinds, positive and negative. The former is that developed on a glass rod by rubbing it with a silk cloth; the latter that developed on a stick of sealing wax by rubbing it with a flannel cloth. Bodies charged with like electricity repel, while bodies charged with unlike electricity attract each other. By the use of suitable instruments it has been shown that ordinarily the atmosphere is charged positively and that the presence of electricity is by no means confined to showery weather or thunder storms. During cloudy weather it may be either positive or negative, but during thunder or snow storms it may change from one to the other with great rapidity.

The electric discharge known as *lightning* is a visible manifestation of atmospheric electricity. It may occur between a charged cloud and the earth or between two oppositely charged clouds. It would seem that the cloud units or vapor particles are individually electrified and that upon condensation into drops the amount of electricity equivalent to that spread over the surfaces of the component vapor particles is, in the case of each drop formed, spread over a surface of much less area. From this it follows that each drop becomes more highly charged than its component units or is at a higher *potential.*

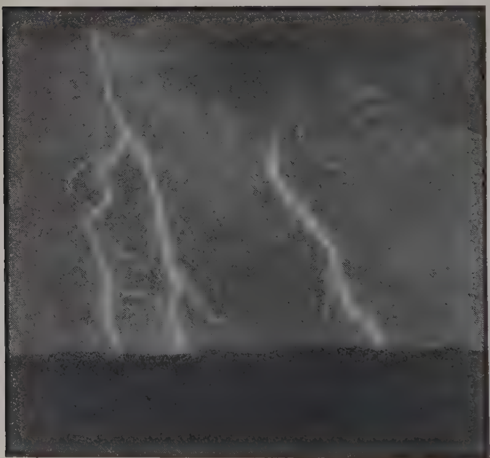
A cloud is formed of a vast number of water drops. As they further unite by condensation the potential of the cloud becomes still greater; that is, the amount of electricity for a given surface area is increased more and more. If, under such condi-

tions, the cloud should approach the earth, a disruptive discharge through the intervening air may take place or the same phenomenon may occur upon the approach of two oppositely charged clouds.

Lightning flashes are of several kinds — stream lightning, zigzag lightning, sheet lightning, and ball lightning.

Stream lightning consists of a broad, straight flash.

Zigzag lightning consists of flashes passing between two bodies of air or clouds, or between a cloud and the earth. Since different portions of the air have different conducting powers, and the electricity follows the path of least resistance, the course of the lightning naturally becomes zigzag. Sometimes the flash is forked.



Zigzag Lightning, from a Photograph

Sheet lightning, frequently called heat lightning, appears as a glow of light illuminating vast clouds and even large areas of the sky. It is probable that this kind of lightning is the reflection of the lightning of some distant storm.

Ball lightning appears in the shape of globular masses of fire, which explode with violence. It is of rare occurrence.

Thunder is thought to be occasioned by the sudden rushing together of the portions of the atmosphere that have been divided by a flash of lightning. It is not often heard at a greater distance than fourteen miles. Occasionally, however, in level regions such as the prairies, it may be heard at a very much greater distance.

The flash is seen instantaneously, because light travels about 186,000 miles in a second. The sound requires about five seconds to travel one mile. Hence if, after seeing the lightning, we count the number of seconds, or pulse

beats, until we hear the thunder, it is easy to ascertain how near the flash has been to us.

In general the electricity does not pass from the air to the earth, but only from one portion of the atmosphere to another. When a discharge to the earth does occur, the effects are often very destructive. The strongest trees, if struck, are rent and stripped of their branches, the sap being suddenly converted into steam, and an explosion actually taking place. Animals and men who are struck are almost always killed.

The Aurora. — Another phenomenon, in which atmospheric electricity apparently plays an important part, is the illumination, often a magnificent display of color, frequently seen near the polar regions of the earth. It takes on a variety of forms. Sometimes it is simply an arch of light spanning the sky from east to west near the horizon, with quivering streamers of white, green, or crimson light, shooting fitfully to the zenith. Sometimes mere masses of colored light are observed. Again the whole heavens are flushed.

In the northern hemisphere it is called the *aurora borealis* ("Northern Lights"); in the southern hemisphere, the *aurora australis* ("Southern Lights"). Of the two displays the former is better known. The zone of its greatest brilliancy is slightly irregular, lying, for the most part, between the parallels of 60° and 70° north latitude. It follows roughly the Arctic shore line of the Eastern Hemisphere, but in the Western Hemisphere it passes southeast from Alaska to Hudson Bay, thence south of Greenland and Iceland to the northern shores of Scandinavia.

Auroras are more frequent as we approach the poles. Within the tropics they are almost unknown. Their law of distribution seems to be the reverse of that which governs the distribution of lightning.

The following facts show that the aurora is an electrical phenomenon: —

(1) The delicate shades of rose, purple, and violet, which characterize the more brilliant auroras, can be produced experimentally by passing currents of electricity through vacua in Geissler tubes or receivers.

It has been computed, from observations of a large number of auroras, that the beams do not usually approach nearer to the earth's surface than 50 miles, and sometimes extend from it to the distance of more than 250. At such altitudes the atmosphere must necessarily be very attenuated, like that through which the electricity is passed in the experiments alluded to.

(2) Direct evidence of the electric character of the aurora is found in the effect produced upon telegraph wires during an auroral display. The aurora has sometimes caused the instruments to work, as though it had been a battery. Sometimes it completely interrupts their work.

(3) The magnetic needle, also, is frequently disturbed during auroras in a degree corresponding to their brilliancy.

Saint Elmo's Fire. — In storms at sea the masts and yards of the ship are sometimes tipped with balls of electric light. They are due to electricity passing without noise, when the clouds are low, between the clouds and the tips of the spars of the ship.

SAINT ELMO'S FIRE

Optical Phenomena. — The most important of all the optical phenomena connected with the atmosphere is also the most common. It is the diffusion of light. This is brought about by reflection and refraction. By the former, light is propagated from particle to particle in the atmosphere. By the latter, it is retained above the horizon when the sun has actually gone down, and it is bent into the atmosphere before he has actually risen above the horizon.

Refraction and reflection give rise to the exquisite variety of colors which deck the morning and evening sky. They also occasion the phenomena of rainbows, parhelia (commonly called sundogs or mock suns), paraselenæ (or moondogs), halos, and mirage.

The rainbow is an arch of colored light which spans the heavens during a storm. It is seen only when the sun is shining at the same time that rain is falling. The descending drops separate the white sunlight into its elementary colors.

Halos are rings of prismatic colors round the sun or moon. They are really circular rainbows, probably due to the refracting power of the ice crystals composing cirrus clouds.

Mirage. Another effect of refraction and reflection is commonly called *mirage*. It is often observed in the desert. Distant villages seem under its influence to be near to the spectator or to be suspended in the heavens above. Sometimes the traveler thinks he is approaching a pool of sparkling water, and hastens to quench his thirst, when he finds that he has been pursuing a mirage.

Mirage is also observed at sea, distant ships being seen elevated above their true position, or even inverted in the air.

PART V. — LIFE

XXVI. ANIMALS AND PLANTS: THEIR RELATIONS AND DISTRIBUTION

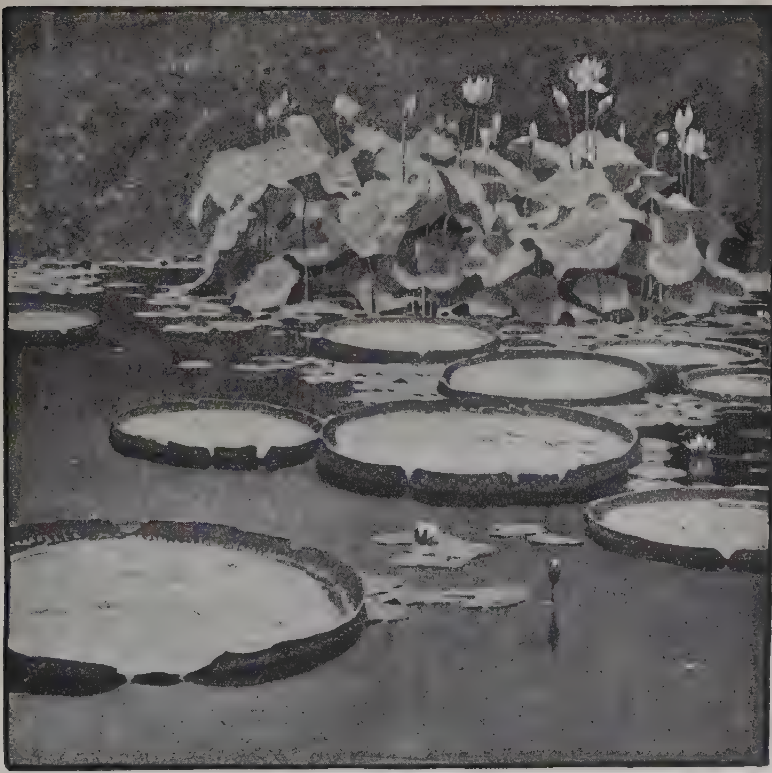
Inorganic and Organic Bodies. — In the preceding chapters attention has been especially directed to the land, the water, and the air. They constitute the inorganic or lifeless portions of the earth. The following pages treat of living bodies, including Man himself. As such bodies are possessed of parts adapted to certain ends, — for example, lungs for breathing, feet for walking, eyes for seeing, — they are said to possess organs having certain functions, hence all such bodies are organic. It is customary, therefore, to speak of mineral matter as *inorganic* and of living matter, or that formed through the process of living, as *organic*.

Of living things two grand divisions are recognized: plants and animals. In the study of Physical Geography it is necessary to consider, first, the relations of each of these divisions to the other; and secondly, their distribution and its causes.

Animals and Plants. — In their higher forms animals and plants are easily recognized, but lower in the scale of life the distinguishing characters of each become less marked until eventually forms are encountered which are recognized as animals or plants with the greatest difficulty and at times with much uncertainty.

The higher animals differ from the higher plants in many particulars, among which mention may be made of the following: They have a nervous system; they are not fixed in position, but possess the power of voluntary motion; they have an internal cavity adapted to the digestion of solid food. The higher plants, on the other hand, are without a nervous system; they are fixed

in position, that is, they are without the power of voluntary motion; and their nourishment, unlike that of animals, being liquid or gaseous, does not require a digestive cavity. In consequence of these distinctions common animals and plants are



VICTORIA REGIA

rarely confused. When, however, the lower forms of animals are reached, especially those which are attached or fixed to foreign objects during the whole or a part of their lives, then there is great danger of mistaking them for plants. The sea anemone and the coral polyp, for instance, are both plantlike in appearance, the spreading tentacles about their mouths presenting a flowerlike fringe.

Plants, in general, differ from animals in their power of transforming inorganic matter into living matter. Animals do not possess that power. Hence for their food animals are dependent, either directly or indirectly, upon plants. Animals feeding upon plants are *herbivorous;* those feeding upon other animals are *carnivorous.* Where there is neither grass nor other vegetable growth, herbivorous animals cannot live; and where they are not found, carnivorous animals, which feed upon them, cannot exist for want of a food supply.

General Facts concerning Distribution. — It is a familiar fact that the same kinds of plants and animals are not found everywhere. Some forms are widely distributed, others are restricted to very narrow limits. The region within which any plant or animal is found is commonly called its *geographical range.* The dandelion and buttercup blossom even amid the glaciers of Greenland. The orange, the date, and banana grow only within or near the tropics. The gigantic water lily called the Victoria Regia has been found only in the basins of the Amazon and Orinoco.

Range Dependent on Climate. — Certain climatic conditions render it possible or impossible for the various species of living forms to exist. Of these conditions by far the most important are temperature and moisture.

The peculiar plants and animals of the torrid zone would obviously die, if placed amid the cold of the Arctic circle; while it is equally certain that the polar bear and his associates would become extinct, if they were exposed to the scorching heat of the tropics.

The early geological history of the globe furnishes striking illustrations of this principle. The entire assemblage of animals that we now find upon the earth did not simultaneously spring into existence. Those species first appeared which were suited by existing climatic conditions. Low forms of animal life prevailed at first, and then higher and higher successively, until such conditions arose as were favorable to the life of Man, and then, at length, his creation took place.

Moreover, many of the animals that once abounded have entirely disappeared. Their existence is attested only by fossil remains. Lynxes, bears,

and hyenas once roamed over the fields of England, and crocodiles swarmed in its rivers; huge mastodons, larger than the modern elephant, flourished on what are now the banks of the Hudson, and browsed amid the forests of Siberia. Their tusks are dug up at the mouth of the Lena and upon the islands of New Siberia, in such quantities as to form an article of regular commerce, under the name "fossil ivory." The climatic conditions favorable to their existence have ceased, and their race has therefore become extinct.

Modifications by Climate. — It would follow as a natural conclusion from the fact that plant and animal life are largely dependent on physical conditions, that changes in these conditions should bring about changes in the plants and animals affected by them. Such we find to be the fact. Modifications of a very extraordinary nature can be affected by varying the "environment" of a plant or animal, and allowing the new environment to be permanent during a sufficient length of time. Many of our most valuable food plants have been thus transformed. The grains in general are believed to have been originally wild grasses.

Our own Indian corn presents a very interesting illustration of climatic modification in a vegetable form. In the South and the Northwest it often attains the height of 12 to 15 feet. As we advance northward through its belt of cultivation, along the Atlantic slope, its height diminishes, until, in New England, it is not usually more than about five feet high. Again, the appearance and quality of its grain have been singularly modified. It is a familiar fact that we have a number of varieties, field corn, sweet corn, pop corn, with white, yellow, brown, and even black grains.

Similar illustrations might be given of the modifications of *animal forms* by changes in their physical conditions. The Shetland pony and the race horse came from one original stock. The terrier, the greyhound, and the mastiff had a common parentage.

Zones of Vegetation. — Since the extent of the geographical range of plants depends mainly on temperature and moisture, it follows that the surface of the earth may be divided into zones of vegetation. These will correspond more or less closely with the

zones of temperature. They will of course be defined not by lines of latitude, but by lines of heat, or isotherms.

The principle of division is this, that within belts or zones having a certain average annual temperature, certain plant growths will flourish; beyond the limits of such zones these characteristic forms disappear, and others are found which are suited to the prevailing temperature. Thus each zone has its characteristic forms of plant life.

Although in naming the zones of vegetation the same terms are employed as in the ordinary divisions by *lines of latitude*, it should be borne in mind that the signification of the terms has been slightly changed in order to accord with *lines of temperature.*

Horizontal Zones. — The surface of the earth may be divided into the following horizontal zones of vegetation: (1) an equatorial zone; (2) two temperate zones; (3) two polar zones.

The Equatorial Zone extends north and south of the equator, and is bounded by the annual isotherms of 70°. It is the zone of greatest heat and most abundant moisture, and consequently of most luxuriant vegetation.

The characteristic growth of this belt is that of the palms. The trees do not lose their leaves in winter.

The Temperate Zones extend northward and southward of the equatorial, and are bounded by the isotherms of 32°F. Here the tropical palms disappear, or are replaced by dwarfed representatives of the family.

The characteristic forms are those of the deciduous forest trees, — those which shed their leaves in autumn and renew them again in spring, — of which the oak, the chestnut, and others belonging to our own forests are familiar examples.

The colder parts of these zones are marked by the abundance of conifers (pines, larches and spruce, and juniper trees).

The Polar Zones extend north and south from the temperate. Within them the average annual temperature is not higher than 32°F., and in many portions it is below 5°. The warmer parts of these zones contain vast forests of spruce, pine, and larch. The

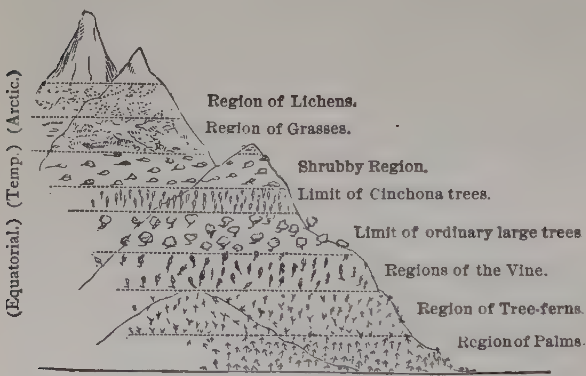
A Group of Date Palms
A scene in the town of Luxor on the Nile.

colder portions are characterized by the growth of dwarfed birch, alder, and willow trees. But beyond certain limits trees

wholly disappear, and only the lower forms of plant life, mosses and lichens, remain.

Vertical Zones. — Since, by ascending sufficiently high, even in equatorial regions, one can pass through every variety of climate, torrid, temperate, and frigid, it is evident that there must be vertical as well as horizontal zones of vegetation.

On the lower slope of the Andes, for example, are found regions of palms and bananas, tree ferns and vines. These correspond to the zone of equatorial vegetation. Higher up are encountered the deciduous trees of the temperate zone. Still farther up there is a region closely resembling the Arctic zone: Conifers are the prevailing type, while deciduous trees are represented by shrubs and dwarfed specimens.



VERTICAL ZONES OF VEGETATION

Near the snow line trees of every kind disappear, and mosses and lichens are the only forms of vegetation that can withstand the perpetual cold.

The Flora of the Sea. — The flora of the sea differs from that of the land in color. It is less inclined to green. The plants of the sea are brown and yellow, pink and purple, green, orange, and violet, with all intermediate shades.

The vegetation of the sea has, like that of the land, a vertical and a horizontal distribution. Both are determined mainly by the temperature of the water and the nature of the sea bed.

In the deepest parts of the ocean nothing but microscopic forms of vegetable life of the simplest kind (called *diatoms*) occur. The smaller algæ or seaweeds scarcely exist below the

depth of 300 feet; the larger are not found deeper than about 60 feet below the surface. The horizontal range of many marine plants is coextensive with the sea. Others, like land plants, have limited ranges.

Among the most interesting kinds of algæ are the *Macrocystis pyrifera*, the *D'Urvillæa utilis*, and the Gulf Weed.

The *Macrocystis pyrifera* measures 700 feet in length. This weed is like a cord. It attaches itself to the rocks, and grows from the bottom in the littoral waters of many countries, and especially along the northwest coast of America.

Few, if any, forms of vegetation have a wider geographical range than this weed. After all traces of plant life on the land have ceased, on approaching the poles, it is still found flourishing in the water.

The *D'Urvillæa utilis* grows in the waters of the Falkland Islands and adjoining regions. The surf often twists it into cables several hundred feet long and as thick as the human body. This, like the *Macrocystis pyrifera*, fastens itself to the rocks, in stormy waters, with such tenacity that sometimes, in the attempt to tear it away, large bowlders are brought up adhering to its roots.

Plants of this species surround Kerguelen Land with such a tangled mass that rowboats find it difficult to get through it. The Straits of Magellan are so thick with these weeds that they fouled the rudder and so entangled the propellers of the first steam vessels that passed through these waters as seriously to interfere with the navigation.

Among the most widely distributed forms of marine vegetation is the Gulf Weed (*Fucus natans*). It is not known whether it grows at the bottom or near the surface of the sea. It is always found afloat, living and growing, but without any signs of roots. It lies so thick in the Sargasso Sea as completely to hide the waters in many places and give the sea the appearance of a drowned meadow.

XXVII. THE DISTRIBUTION OF USEFUL PLANTS

Food Plants. — It will be of interest to consider the geographical distribution of those plants that are of the greatest importance to man. Of these, the grains or cereals, as they are called (barley, rye, wheat, Indian corn, rice, and millet), deserve first attention. Certain of them have, of all plants, the widest geographical range.

Barley is cultivated in Europe as high as 70° north latitude, and on the Asiatic table-lands at an elevation of 13,000 feet.

Rye will grow in all regions between 67° north and south latitude.

Wheat has a range almost equal to that of rye. It ripens in North America as far as latitude 55°, and in Europe, owing to the influence of tempering winds and currents, as far as latitude 64°. In Mexico and the Andean region its culture begins at the height of about 2500 feet and is successful as high as 10,000. Upon the Himalayas it is cultivated as high as 12,000 feet above the sea.

Indian corn will grow and ripen in the open air, from the parallel of 45° or 50° north to the corresponding parallel south. Its range embraces two thirds of the earth's surface. In the torrid zone neither wheat nor Indian corn do well at the sea level, though they produce finely on the mountain sides.

Rice is limited in its geographical range by the parallels of 45° north and 35° south. This belt covers more than half the surface of the earth. The plant thrives best in low and swampy ground, and is the chief cereal cultivated in China and Japan. Its grain is the principal article of food for one third of the entire human race.

Millet is the most prolific of the cereals. It is adapted better than any other to the vicissitudes of a tropical climate. In

Egypt, Arabia, Turkey, and Italy it is an important article of food, and in India it, and not rice, is the staple food grain.

Nearly allied to the cereals as an article of diet is the potato. It has a range almost equal to that of barley. It is probably a native of Chile or Peru, but will grow in Iceland.

In the low, damp, and hot portions of the equatorial region

BREADFRUIT

wheat and corn are replaced by rice and the banana, manioc or mandioca, and the breadfruit.

The banana, indigenous in the regions of intertropical America, is, as an article of food for the masses, what rice is to the Hindu, the potato to the Irish, and wheat to the European. An acre of ground planted in bananas requires less cultivation and yields more abundantly than any other food plant. Humboldt estimated the yield to exceed that of the potato 44 times,

and that of wheat 133 times. The banana flourishes 4000 feet above the sea.

Manioc or Mandioca is a native of South America. It is also extensively grown in Africa and other tropical regions. Its large turniplike root, dried and grated, is known as cassava, and purified as tapioca. It is an article of food for a large part of the population of South America.

Breadfruit is characteristic of the islands of the Pacific. Its fruit furnishes the natives with food somewhat resembling bread.

Sugar cane, so far as we know its history, seems to have been a native of India or China. It grows in the warm latitudes of every continent.

Beverage Plants. —The chief plants which yield beverages, tea, coffee, and cacao, are grown in warm regions; tea in China and Japan, India, and Ceylon; coffee in southern Asia, central Africa, and the tropical portions of North and South America. Cacao is a native of the tropical regions of North and South America.

NUTMEG

Spices and Narcotics.— The geographical range of the spices, such as cinnamon, nutmeg, ginger, pepper, cloves, and allspice, or pimento, is narrow. It is confined to a few degrees north and south of the equator. The East Indies are specially the region of the spices.

The important narcotics, tobacco and opium, are natives of

warm regions, but their geographical range extends into the temperate zones.

Plants used for Clothing. — The principal plants which are used for textile fabrics and clothing are cotton, flax, and hemp.

Cotton, the most important of them all, will grow and mature well at moderate heights, anywhere between the parallels of $37\frac{1}{2}°$ north and south. This belt being 75° of latitude broad, and extending entirely round the earth where its circumference is largest, gives for this plant a geographical range that embraces more than half the earth's surface.

The United States, Brazil, India, and Egypt are the chief cotton-growing countries.

Flax and hemp are confined to the climates of the temperate zone, and are brought to their greatest perfection between the parallels of 25° and 50° north.

The Medicinal Plants, such as yield sarsaparilla, jalap, castor oil, quinine, gums, and balsams, are almost all indigenous to the torrid zone.

Foremost among them stands the cinchona, from which quinine is obtained. Is is a native of the eastern slopes of the Andes, flourishing in a belt that extends through Bolivia, Peru, and Equador, from 3000 to 9000 feet above the sea level. It has been successfully acclimatized in India.

Useful Trees. — The ornamental woods and dyewoods, such as mahogany, rosewood, sandalwood, and logwood, are confined to the torrid zone. The oak, walnut, chestnut, maple, ash, with pines, firs, and cedars, belong to the cooler latitudes.

The geographical range of the oak extends from the tropics to the verge of the frigid zone. The timber trees of the temperate zone are replaced in the torrid by the teak and bamboo.

XXVIII. THE DISTRIBUTION OF ANIMALS

General Statements. — Animals, like plants, require a certain temperature for the maintenance of their life. Furthermore, no animal except Man can inhabit regions in which nature does not spontaneously provide for it suitable food; and hence the fauna of every country is dependent on its flora. For these two reasons the distribution of animals, like that of plants, depends mainly upon climate.

Zones of Animal Life. — In view of this fact it is usual to divide the earth's surface, in relation to its fauna, into the equatorial, temperate, and polar zones, as has been done in treating of the distribution of plants.

The Equatorial Zone is characterized by the abundance of its forms of animal life. It is the zone of lions, tigers, rhinoceroses, elephants, camels, crocodiles, poisonous serpents, and birds of the most brilliant plumage.

The temperate zones, on the other hand, are distinguished by the number of their useful animals, such as the ox, cow, horse, sheep, and goat. The eagle, turkey, and pheasant are among the birds. In coloring, the animals of temperate regions are far less brilliant than those of the Equatorial Zone.

In the Arctic regions (for of the Antarctic we know little) are found the fewest species, although the individuals are numerous. The reindeer, musk ox, white and brown bear, wolves, white foxes, and sables are the chief land animals. The seal, walrus, and whale frequent the waters. Reptiles are unknown. Ducks and gulls abound.

Zoölogical Regions. — It is obvious that any division of the earth's surface into zones characterized by peculiar fauna and flora is necessarily far from exact. Although the distribution

of life on the globe is mainly dependent on climate, it is not so altogether.

For, in the first place, many species overlap, being found in more than one zone. The dog is the companion of Man in every zone; sugar cane grows in both torrid and temperate regions.

CHIMPANZEE

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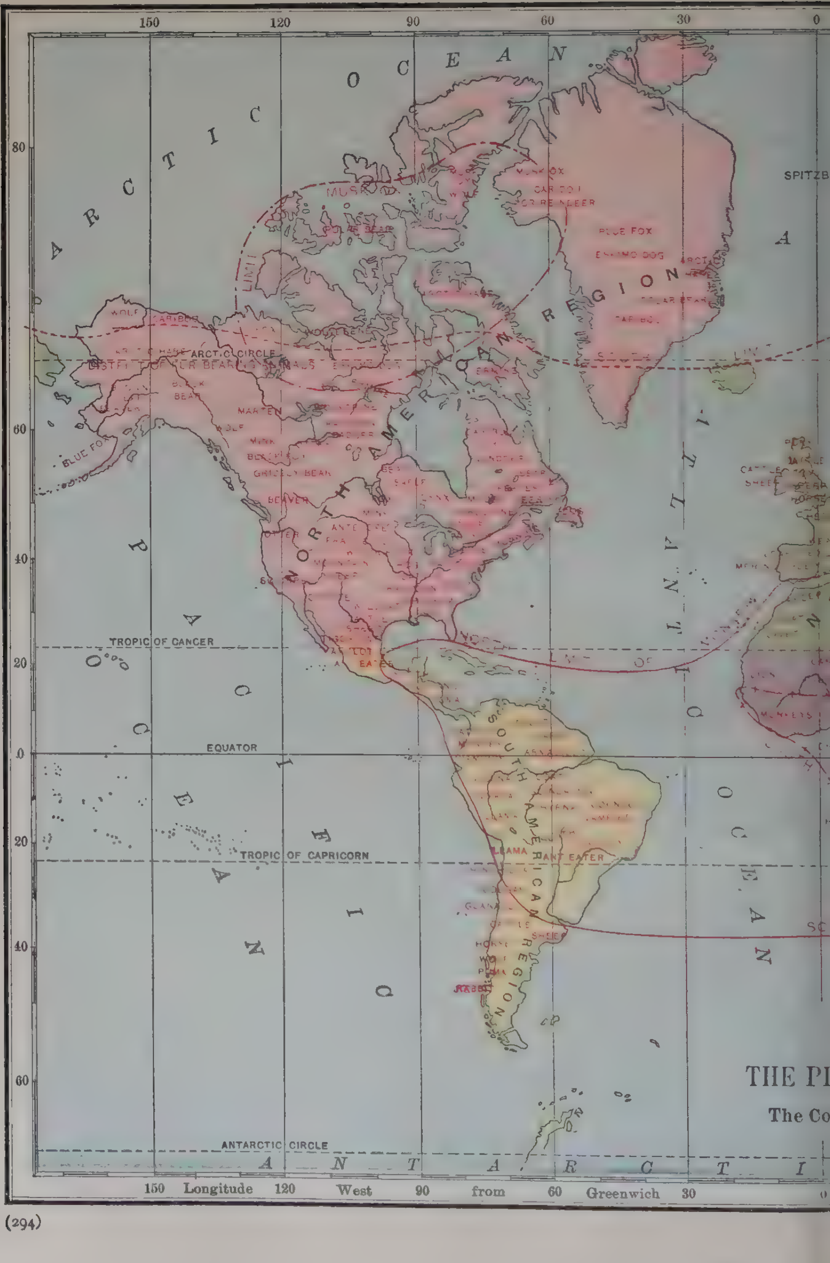
And in the second place, however alike in climate different portions of the earth's surface may be, they do not necessarily have the same flora and fauna. The isotherms of the United States traverse also the Empire of China. Yet there are marked differences between the forms of plant and animal life which characterize the two regions. The isotherms of 68° F. pass through Australia, South America, China, and the Gulf region of the United States. But the vegetation and animal life of these regions are strikingly diverse.

From these considerations scientific men have been led to seek a mode of division more in harmony with existing facts than that represented by zones, and the plan proposed by the eminent



150
120
90
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80
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40
60
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
NORTH AMERICAN REGION
SOUTH AMERICAN REGION
ARCTIC CIRCLE
TROPIC OF CANCER
EQUATOR
TROPIC OF CAPRICORN
ANTARCTIC CIRCLE
MUSK OX
BLUE FOX
ESKIMO DOG
WOLF
MARTEN
BEAVER
GRIZZLY BEAR
LLAMA
ANT EATER
150 Longitude 120 West 90 from 60 Greenwich 30

TRIBUTION OF
PAL LAND ANIMALS
licate the Zoological Regions
ARCTIC CIRCLE
TROPIC OF CANCER
EQUATOR
TROPIC OF CAPRICORN
ANTARCTIC CIRCLE
WHITE BEAR
WHITE OR POLAR BEAR
REINDEER
DISTRICT OF FUR BEARING ANIMALS
OLD WORLD REGION
ERMINE
OTTER
SABLE
MARTEN
BEAR
FOX
WOLF
MINK
BROWN BEAR
HARE
ELK
BEAVER
CATTLE
WOLVERENE
ARGALI
STAG
LYNX
HORSE
GOAT
SHEEP
BACTRIAN CAMEL
WILD SHEEP
CHEETAH
LEOPARD
MUSK DEER
YAK
ASS
GAZELLE
HYENA
DROMEDARY
INDIAN REGION
TIGER
ELEPHANT
HONEY BEAR
WILD BOAR
SNUBLF MONKEY
BUFFALO
ORANG UTAN
CHAMELEON
ANTELOPE
KANGAROO
WOMBAT
DINGO
ORNITHORYNCHUS
AUSTRALIAN REGION
ANTELOPE
HIPPOPOTAMUS
RHINOCEROS
GIRAFFE
ZEBRA
LEMUR
TENREC
ELEPHANT AND RHINOCEROS
OF MONKEYS
O C E A N
I N D I A N
P A C I F I C
30 Longitude 60 East 90 from 120 Greenwich 150 180
L.L.POATES ENGR'S CO., N.Y.

naturalist Sclater, and more exactly defined by Mr. Wallace, seems to be the most satisfactory thus far devised.

According to this division the surface of the earth is made up of *six regions*, each of which has certain forms of life peculiarly its own and not found elsewhere, although it may have

BARBARY LION

From photograph. Used by permission of the New York Zoölogical Society.

many species in common with other regions. The following are the names of the regions with their leading characteristic forms.

(1) *The Northern Old World Region* includes all of Europe, all temperate Asia north of the Himalayas, and northern Africa down to the Tropic of Cancer. Here we find the bear, wolf, deer, horse, cow, and camel, the wild goats, the eagle, the corn-crake, and bustard.

Peculiar to this region are almost all the known species of goats and sheep, moles and dormice; and among birds the nightingales, magpies, and almost the entire group of pheasants.

(2) *The Ethiopian or African Region* embraces Africa south of the Tropic of Cancer, southern Arabia, and the island of Madagas-

car. Here we lose sight of certain forms familiar in the Northern Old World Region, bears, deer, moles, and true pigs; and camels and goats, except in the desert regions, are equally wanting.

Peculiar forms are the gorilla, chimpanzee, and baboon, the hippopotamus and giraffe, the guinea fowls, most of the weaver birds, and the secretary bird.

HIPPOPOTAMUS

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Madagascar and the neighboring islands, though classed as parts of the Ethiopian region, have a fauna peculiar to themselves. This insular sub-region is one of the most wonderful in the world from a zoölogical point of view. It is especially characterized by the abundance of lemurs (nocturnal animals somewhat resembling monkeys, but very small); while most of the groups in which Africa is especially rich — apes, lions, leopards, giraffes, antelopes, and elephants — are wholly wanting. Some of the birds are entirely unlike all other known species.

(3) *The Indian Region* comprises India, Indo-China, and the East Indian Islands as far as the Strait of Makassar.

Peculiar to this region are the orang-outang, the tiger, the honey bear, the civet, and flying lemurs; and among the bright-feathered

birds, the argus pheasant, the peacock, the trogon, and the curious little tailor birds.

(4) *The Australian Region* consists of Australia, New Zealand, Polynesia, and those of the Malayan islands that lie east of the Strait of Makassar.

This region has a fauna of marked peculiarity. It is notable for the absence of forms elsewhere almost universal. The higher mammalia of other regions are replaced by mammals (such as the duck mole) that lay eggs; and by marsupials (that is, animals with a pouch for holding their young). Of these none are found elsewhere, except the opossum of North and South America. Among the marsupials of Australia are the kangaroo, the tree kangaroo, and the wombat.

THREE-HORNED GIRAFFE

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The bird life of this region is rich in handsome and peculiar forms, such as the beautiful bird of paradise, the crimson lory, the lyre bird, the bower bird, the emu, and the cassowary.

(5) *The North American Region* includes North America and adjacent islands north of the Tropic of Cancer.

The fauna of this area and that of the Old World region present marked dissimilarities. Here we do not find native

the horses, asses, cows, sheep, pigs, hedgehogs, and dormice of the Old World. They are replaced by the bison (nearly extinct), raccoons, opossums (marsupial), prairie dogs, and

ORANG-OUTANG
From photograph. Used by permission of the New York Zoölogical Society.

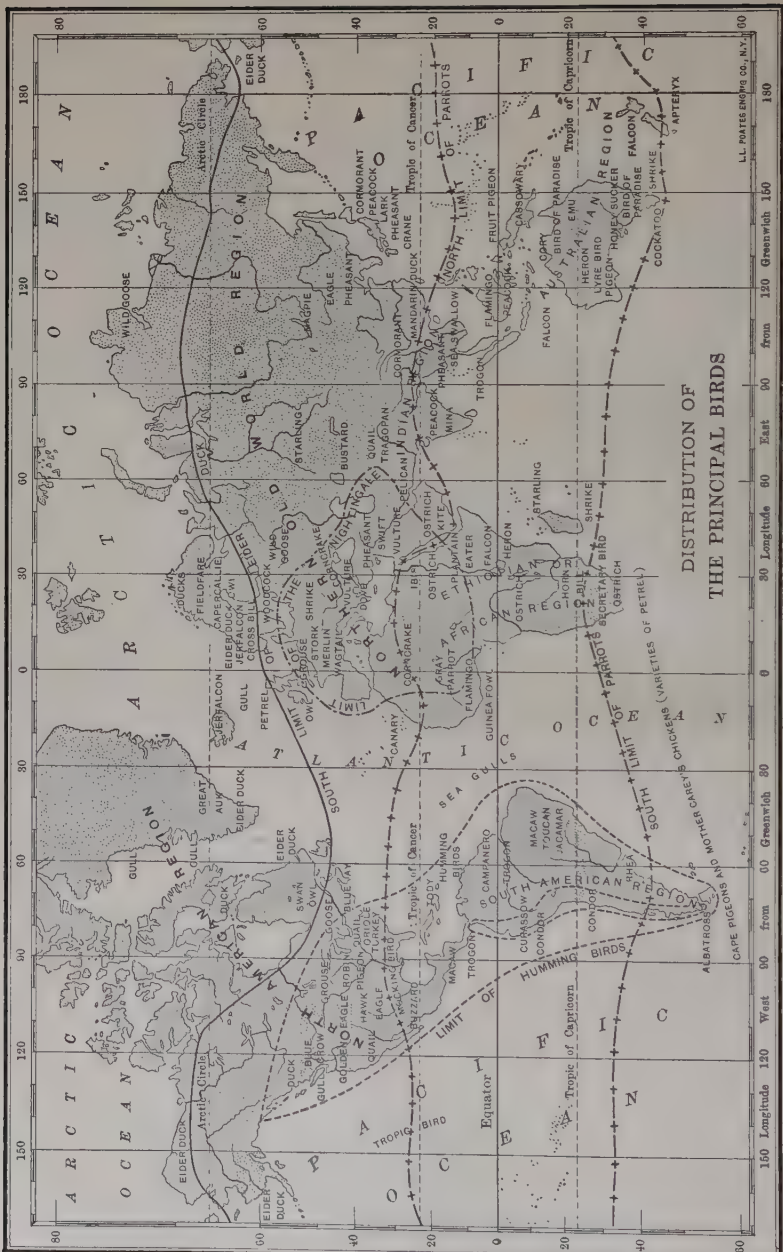
skunks. The thrushes, wrens, robins, and finches are represented by new families.

Among animals peculiar to this region are the grizzly bear, the pouched rat, the mocking bird, the blue jay, the blue crow, and the rattlesnake.

It is hardly necessary to say that many Old World forms have been introduced.

(6) *The South American Region* embraces South America and that portion of North America and the outlying islands which are south of the Tropic of Cancer.

Of all the regions this is the most remarkable for the fewness of the forms which it contains in common with others. No



DISTRIBUTION OF
THE PRINCIPAL BIRDS
ARCTIC OCEAN
ATLANTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
OLD WORLD REGION
NORTH AMERICAN REGION
SOUTH AMERICAN REGION
ETHIOPIAN REGION
INDIAN REGION
AUSTRALIAN REGION
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
LIMIT OF THE NIGHTINGALE
NORTH LIMIT OF PARROTS
SOUTH LIMIT OF PARROTS
LIMIT OF HUMMING BIRDS
CAPE PIGEONS AND MOTHER CAREY'S CHICKENS (VARIETIES OF PETREL)
EIDER DUCK
WILD GOOSE
GULL
GREAT AUK
JERFALCON
PETREL
CANARY
SEA GULLS
TROPIC BIRD
ALBATROSS
CONDOR
RHEA
MACAW
TOUCAN
JACAMAR
CURASSOW
CAMPANERO
TROGON
HUMMING BIRDS
TODY
BUZZARD
MOCKING BIRD
TURKEY
ORIOLE
QUAIL
BLUE JAY
ROBIN
PIGEON
HAWK
EAGLE
GOLDEN EAGLE
GROUSE
BLUE CROW
SWAN
OWL
GOOSE
DUCK
FIELDFARE
CAPERCAILLIE
CROSS BILL
WOODCOCK
STORK
SHRIKE
MERLIN
WAGTAIL
CORNCRAKE
VULTURE
DOVE
SWIFT
PHEASANT
IBIS
OSTRICH
KITE
PLANTAIN EATER
FALCON
HERON
GRAY PARROT
FLAMINGO
GUINEA FOWL
HORNBILL
SECRETARY BIRD
STARLING
BUSTARD
QUAIL
TRAGOPAN
PELICAN
PEACOCK
MINA
SEA SWALLOW
MANDARIN DUCK
CORMORANT
MAGPIE
LARK
CRANE
FRUIT PIGEON
CASSOWARY
BIRD OF PARADISE
LORY
EMU
LYRE BIRD
HONEY SUCKER
COCKATOO
APTERYX
L.L. POATES ENG'G CO., N.Y.

horse or ass, ox, sheep, or goat is a native of South America. The wild cattle and horses which now roam over its plains and pampas are the offspring of animals introduced by Europeans.

This region is equally remarkable as containing a greater number than any other of forms which are strictly its own. Among these are the sloth, the armadillo, the llama, the alpaca

GREAT GRAY KANGAROO

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and chinchilla, the blood-sucking vampire bat, the prehensile-tailed monkey,[1] and the destructive boa-constrictor.

Here alone we find the condors, toucans, todies, rheas, curassows, and mot-mots. The forest-clad slopes of the Andes are alive with the murmur of 400 species of humming birds, some of which pass their existence near the limits of perpetual snow.

Range of Draught Animals. — Of special interest is the geographical range of those animals which Man employs as draught animals or beasts of burden.

The horse, the ass, and the ox, either native or introduced, are found wherever grains and grasses grow. Beyond the

[1] Monkeys whose tails are capable of grasping the branches of trees.

limits of these food plants the reindeer and the dog become the draught animals. The reindeer is fitted to browse upon Arctic mosses, and has the instinct of searching for them

SILVER-TIP GRIZZLY BEAR
From photograph. Used by permission of the New York Zoölogical Society.

beneath the snow. He presents one of the most striking cases of an animal adapted to the peculiar conditions of his habitat.

In the equatorial regions of the Old World we find the elephant serving as a beast of burden; while to the northward, especially in desert regions, the camel and dromedary are employed.

The cushioned foot of the camel enables him to tread firmly upon the shifting sands of the desert, while his capacity for carrying an extra supply of water adapts him wonderfully for journeying through its dry and thirsty wilds.

In South America, where, to traverse the continent, the traveler has to scale the snowy heights of the Andes, there —

South American Condor

From photograph. Used by permission of the New York Zoölogical Society.

The Camel as a Beast of Burden

and not in North America, where the mountains have gaps that the buffalo could cross — was found the *llama*, the camel of the New World, the only beast of burden in use among the native Americans at the time of the discovery of the continent.

MALAY TIGER

From photograph. Used by permission of the New York Zoölogical Society.

The llama, with the alpaca and vicuna, which are different species of the same genus, have their habitat along the edge of the snow line on the Andes, where the atmospheric pressure is not more than eight or ten, instead of fifteen, pounds to the square inch.

This diminished pressure of the atmosphere has very marked effects upon both man and beast. To one from the lowlands, respiration, in these elevated regions, is difficult. Mules are used for the transportation of merchandise between these places and the seaboard, but never ascend beyond a certain height. At the elevation of 5000 or 6000 feet they are met by the llamas of the tableland, and the cargoes are exchanged.

Without the camel and the llama Man, in the early stages of civilization, could have neither crossed the deserts of the Old World, nor scaled the cloud-capped mountains of the New.

Among the fastnesses of the Himalayas, and upon the bleak heights of the

plateau of Tibet, the beautiful *yak* serves as a beast of burden. He is to be seen browsing at an elevation of 17,000 feet above the sea. What the camel is to the Arab, what the llama is to the Peruvian, the yak is to the native of Tibet.

Limited Range of Some Animals. — Many animals are confined to a very narrow geographical range by causes that are

TWO-TOED SLOTH

From photograph. Used by permission of the New York Zoölogical Society.

in some cases quite obscure. The little chinchilla, with its beautiful fur, has its habitat on the Andes of Chile and Peru, 8000 to 12,000 feet above the sea.

The chamois inhabits the belt of the Alps which lies between the trees and the snow line.

The Kashmir goat, noted for its fine wool, is restricted to the valleys of the Himalayas.

The ostrich of Africa, the rhea of South America, the emu of Australia, the cassowary of New Guinea, the apteryx of New Zealand, are birds which neither fly nor swim. Their geo-

graphical range therefore is very limited. The same was true of the dodo of Mauritius and the æpyornis of Madagascar.

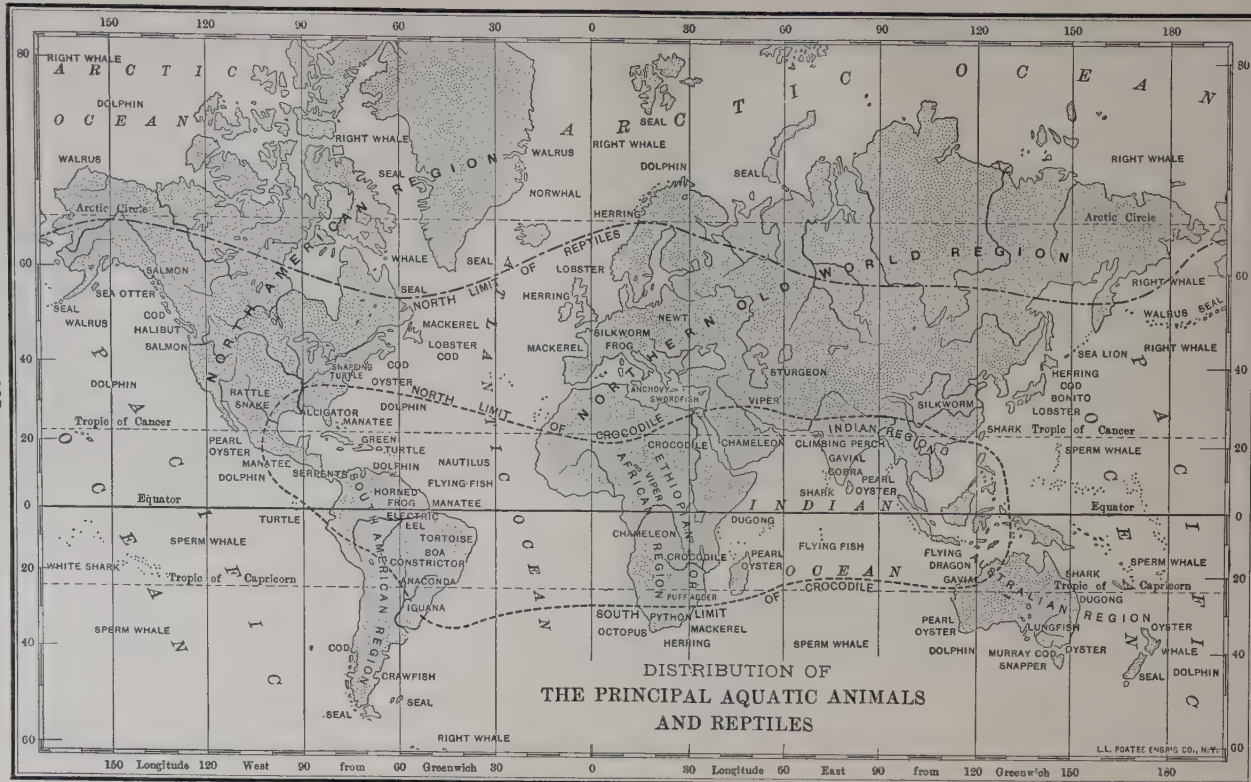
Animals of limited range are the most likely to become extinct. The apteryx is nearly so; the dodo has become so

SOUTH AMERICAN LLAMA

From photograph. Used by permission of the New York Zoölogical Society.

within two centuries; and the æpyornis became so at a very recent period, for one of its eggs (eight times as large as that of an ostrich) was found and brought to Europe in 1851.

Fauna of the Sea. — As with the animals of the land, so with those of the sea — different species have their geographical range, both vertical and horizontal, beyond the limits of which the conditions necessary for their existence are not found. This, however, is less rigidly true with regard to the fauna of the sea than that of the land. It is quite obvious that temperature must be the main element which determines the habitat of marine animals. Other matters, such as the nature of the sea bottom, have a minor influence.



DISTRIBUTION OF
THE PRINCIPAL AQUATIC ANIMALS
AND REPTILES

Life of Tropical Waters. —The waters of the tropics, like the shores which they bathe, teem with the greatest variety of animal forms. Many of the fish and crustaceans are decked with colors of surprising brilliancy.

The sperm whale inhabits the warm waters of this zone, and is most abundant in the Pacific Ocean. Flying fish, albacore, bonito, and sharks are all inhabitants of intertropical seas. Pearl oysters, also, with corals and sponges, are found in this belt.

APTERYX
From Nicholson and Lyddecker.

Life of Cooler Waters. — In the cooler seas of the temperate and Arctic regions we find the greatest abundance of fish that are of value to Man. All the famous food fisheries in the world — those of the cod, the herring, the mackerel, and others — are in the waters of cold currents.

The Grand Banks of Newfoundland, the fisheries of the North Sea, and those of the Pacific coasts of America, China, and Japan, all lie within the range of the cold flow from the north. It is to the presence of the cold current along our Atlantic seaboard that our own fish markets owe their celebrity.

The right whale is found in the cold waters of polar seas. Those of the torrid zone are as impassable to him as a sea of flame. So true is this that the right whale of the northern hemisphere and the right whale of the southern are restricted each to his own zone.

Although the seal may be found in all latitudes, his favorite haunts are the islands of Alaska, the shores of Labrador, and the bays of southern Chile and Argentina. Other inhabitants of polar waters are the sea lion,

hunted for his fur, and the walrus, hunted for his ivory tusks, which are superior to those of the elephant, and the narwhal, or sea unicorn, whose ivory horn is eight or ten feet in length.

Various depths are suited to various species of marine animals. The reef-building polyp cannot flourish at a greater depth than about 150 feet below the surface. Lower down, in depths so great as 1500 or even 2400 fathoms, living forms are found, but they are of a low order — foraminifera, sponges, starfish, and mollusks. The bathymetrical range of such creatures is surprisingly great.

The Floras of the Zoölogical Regions. — The flora of each region may not perhaps be so distinctly marked as the fauna.

WEST INDIAN BOA

From photograph. Used by permission of the New York Zoölogical Society.

There will naturally be much overlapping, many species being very widely diffused, and some being common to all parts of the globe. Still, we ought to find some characteristic floral peculiarities in each region.

The *Old World* region is the native home of all the cereals excepting maize, of the apricot, the cherry, the apple, the pear, the olive, the cork oak, and sycamore fig.

The *Ethiopian* region has among its peculiar vegetable forms the baobab, the oil palm, and coffee.

The *Indian* region is characterized by the banyan, the fig, the mango, cinnamon, the guttapercha and teak trees, and the sweet potato.

The *Australian* region has a flora very distinct from that of all others. The leaves of the trees are of a peculiar bluish green hue, and strangely present their edges to the sun, arranging themselves vertically instead of horizontally. The eucalyptus or gum trees, of which there are 400 varieties, are probably the loftiest trees in the world. Many are 400 feet high. One monster was felled which measured 480 feet. The beefwood trees are remarkable. Instead of leaves, of which they have none, they have sheaths inclosing their branches. They thus resemble in structure the "horsetail" with which we are familiar.

The *North American* region is the native home of the magnolia, the live oak, the *Sequoia gigantea* (giant trees of California), and persimmon. Nearly 400 species of trees are peculiar to this region.

The *South American* region is distinguished by the multitude of its parasitic forms. Peculiar to it are the cinchona, the cacao, the manioc, the potato, the sarsaparilla, the *Victoria Regia*, and the passion flower.

XXIX. MAN

Range of Human Habitation. — Man dwells in every zone and at nearly all altitudes. He is literally cosmopolitan. Unlike the irrational animals, he can to a large extent overcome the force of external conditions. He can protect himself from the severity of the winter's cold, and maintain his existence amid the snows of the Arctic regions; and on the other hand he can endure the fierceness of intertropical heat. Thus his horizontal range is almost unlimited.

He has, again, an ample vertical range. The lowest place where men have established permanent dwelling places is in the valley of the Dead Sea, 1300 feet *below* the sea. The highest is at the convent of Hanle, inhabited by twenty Tibetan monks, 16,533 feet *above* the sea. These limits include a vertical range of more than three miles.

The Unity and Diversity of the Human Family. — Wherever Man is found, he presents the same essential features of body and of mind. No such differences sunder men as those which exist between the horse and the lion, the eagle and the ostrich. The human family is of one blood.

Still the heat and cold to which man is habitually exposed, the food upon which he lives, and the physical conditions generally by which he is surrounded will, in the lapse of time, produce certain effects upon his bodily and intellectual organization. Hence we find wide diversities characterizing different portions of the human family. Men differ in color, in feature, in mental and moral peculiarities, industrial habits, social and governmental institutions.

Division into Races. — Some ethnologists divide the great human family into three, some into five, others into six or even a larger number of races.

ARCTIC OCEAN
NORTH LIMIT OF PERMANENT INHABITANTS
Samoyeds
Yakuts
Koriaks
Eskimos
Athabascans
Finns or Ugrians
Tanguses
Kamchatdales
Manchurians
Aleutians
Kirghiz
Tatars and Mongolians
Japanese
Afghans
Tibetans
Chinese
CAUCASIAN
Hindus
Dravidians
Indo-Chinese
TROPIC OF CANCER
Hawaiian
Micronesians
MALAY
MONGOLIAN
Dyaks
Melanesians
Polynesians
Tahitians
NEGRO
INDIAN OCEAN
PACIFIC OCEAN
CAUCASIAN
Maoris
ANTARCTIC CIRCLE
Longitude East
Longitude West
RACES OF
Caucasian.
Mongolian.
Negro.

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The five great races of mankind, as generally recognized, are the *Caucasian* or white, the *Mongolian* or yellow, the *Negro* or black, the *Malay* or brown, and the *Indian* or red.

The Caucasian Race derives its name from the Caucasus range of mountains, because of the tradition that the region traversed by these mountains was the birthplace of the race.

The chief divisions of the Caucasians are: (1) the Indo-European, comprising the Hindus, Persians, Circassians, Slavonians, Teutons, and Celts; and (2) the Semitic families, of whom the Hebrews and Arabs are the most important.

CAUCASIAN

The term Indo-European is derived from the fact that this division of the race has established itself all the way from India to the farthest bounds of Europe.

Nine tenths of the people of the United States, as well as all the peoples of Europe, except the Lapps, Finns, and Magyars, and the Turks proper, belong to the Caucasian race. Both of the Americas are governed by it. Africa is controlled by it. In Asia, it dominates from the shores of the Mediterranean, through Arabia, and Persia, and along the southern slopes of the Himalaya Mountains beyond the banks of the Brahmaputra.

The Caucasians are the most symmetrical in figure, comely in person, and beautiful in feature, of all the branches of the human family. The numerous divisions and subdivisions of the race vary in complexion according to the region they occupy. The extremes are the Germans with their flaxen hair, blue eyes, and

fair skin, and the Hindus with raven locks, black eyes, and olive-brown or brownish black skin. The face of the Caucasian is oval, the head ample; the hair full and often curled or wavy.

In intellect this race ranks first. With very few exceptions all the leading thinkers of the world have been Caucasians; and without any exception all the great discoveries of recent times have been made by members of this family.

To this race has been assigned the task of civilizing and enlightening the world. Its social habits and its governmental institutions, its educational systems and its religious views, are those which most conduce to the elevation and happiness of mankind.

MONGOLIAN

Wherever the white man establishes himself he speedily becomes dominant; while the communities of other races into which he introduces himself are commonly subjected to a gradual process of extinction.

The Mongolian Race derives its name from the Asiatic tribe of Mongols. The Chinese, Indo-Chinese, Japanese, Tibetans, Samoyedes, and Turks in Asia, the Finns, Magyars, and Lapps in Europe, and the Eskimos of the Arctic regions of North America are branches of this race.

The color of the Mongolian is olive-yellow. His face is broad, with wide and flattened nose, and small, obliquely set eyes. His hair is straight, coarse, and black. In stature he is somewhat below the ordinary standard of the Caucasian.

In intelligence and moral character he ranks next to the Caucasian.

Branches of the Mongolians, as the Eskimo, are very low in the intellectual scale. Not so the Chinese and Japanese. It is true that, in the past, they have displayed the mental inactivity which marks the Mongolian in general. They remained for ages just where their ancestors had been. A great change, however, is going on. The establishment of a constitutional form of government by the Japanese, and their adoption of many important features of European civilization, entitle them to rank among the progressive nations of the world.

NEGRO

The same may be said in a less degree of the Chinese.

Something also must be said in commendation of the native civilization of both these great Mongolian communities. China has had a Governmental system which has stood the test of ages. Japan, too, has been a prosperous and well-ordered state for generations of which we have no count.

In religion the Mongolians are generally Buddhists.

The Negro Race is so called from the color of its skin (Latin, *niger*, black). It occupies nearly the whole of the African continent. The hair of the Negro is short and curly; his nose is flat, wide, and upturned; his cheek bones are prominent, and his lips thick.

The moral and intellectual status of the Negro in his native land is low. When brought into contact, however, with the

Caucasian race, he shows himself capable of considerable elevation.

The native Australians, though classed by some ethnologists as a separate race, may properly be regarded as a branch of the Negro family. They are probably the most degraded members of the human species. Before the European settler they are rapidly dying out.

The Malay Race is held by some to be a branch of the Mongolian. Its characteristics are, however, sufficiently marked to entitle it to separate classification.

MALAY

The Malays occupy a part of southeastern Asia and most of the islands of the Pacific. The Malay peninsula, Sumatra and Java, Borneo, Celebes, Formosa, the Philippines, New Zealand, and the Polynesian Islands, all had this race for their aborigines.

The members of the Malay race are of medium height, with well-proportioned limbs. Their color varies from olive-yellow to brown or black. Their hair is coarse and black.

Intellectually and morally the Malayan is of a low order. Some of them, however, have a written language and a legal code. They are true sea rovers, and prone to piracy.

The American Indians constitute what some ethnologists designate as an offshoot of the Mongolian race. At the time of Columbus they had spread all over North and South America.

Some of the better known tribes are the Chippeways, Da-

kotas, Apaches, and Cherokees in North America; the Caribs, the Araucanians, and Patagonians in South America.

The American Indian is copper-colored or red, and therefore he is often called the Red man. His hair is black, coarse, and straight, his cheek bones prominent. In person he is tall and lithe. He is remarkable for his endurance of fatigue and his disregard of pain. Intellectually and morally he occupies a medium position among the races of mankind.

AMERICAN INDIAN

The Incas of Peru and the Aztecs of Mexico were found in a remarkable state of civilization by Pizarro and Cortez; and there are, in Central America and in New Mexico and Arizona, interesting memorials of a long-forgotten civilization which had its home in those regions.

The Montezumas of Mexico had their halls, their academies and schools, their zoölogical and botanical gardens, their calendar and their monuments. Their capital, at the time of Cortez, vied with the wealthiest cities of Europe.

Conditions Favorable to Civilization. — From this brief review of the races it will be seen how powerful has been the influence of physical circumstances upon Man. Some portions of the human family have remained hopelessly barbarous; some have received civilization from others; and some, again, have originated a civilization of their own — an *indigenous* civilization. Wherever this last has occurred, it has invariably been neither at the poles, nor in the hot lands of the tropics, but rather in a middle ground between the two. It is here that conditions best adapted to man's physical development are found.

An indigenous civilization has never had its origin under the blighting blasts of the Arctic regions. Life there, from the cradle to the grave, is a continuous struggle for mere subsistence. The body is so pinched and starved by cold and hunger as to prevent the development of the mind.

Neither do the moist and overheated climates of the torrid zone appear to be favorable to mental development. There the rainy season and the constant heat dwarf and enervate the body. Cold may not pinch, nor hunger gnaw, yet fever racks the frame; and the mind, in its first and feeble steps toward civilization, is crippled by the ills of the body. Body and mind, moreover, lack in the torrid zone, by reason of its superabundant productiveness, the great stimulus to human exertion, — necessity.

Man, to be civilized, must be beyond the reach of climatic extremes.

Man's Influence upon Physical Geography. — While, however, we notice the influence of physical geography upon Man, we must also notice the influence of Man upon physical geography. Although, like the brutes, he is strongly impressed by his material surroundings, he is unlike the brute creation in this: They cannot modify the conditions which surround them; he can. The methods to which he resorts are mainly three: (1) Drainage, (2) Irrigation, (3) Extension of the range of useful plants and animals.

In many cases skill and perseverance triumph over natural difficulties that seem insuperable.

Immense changes are wrought by artificial drainage. Superfluous water, instead of being left to form marshes, saturate the soil, and be taken up by evaporation, is carried off underground through the drain pipes; consequently, the air is not so largely impregnated with moisture as formerly, and the soil, instead of being constantly chilled by evaporation, is rendered warm, genial, and productive.

This result is particularly noticeable in England and Scotland, where very extensive areas have been drained and brought under cultivation.

Holland has been reclaimed from the sea. The water has been diked out; and many parts of the country that were the bottom of the sea are now dry land, and though below the level of the sea, form the home of industrious and happy communities.

Years ago there were "drowned lands" along the lower banks of the Mississippi, subject to overflow, and uninhabitable, embracing an area larger in the aggregate than the state of New York. Many of these lands have now been reclaimed by means of levees.

The dike lands of Nova Scotia and New Brunswick have been reclaimed from the sweeping tides of the Bay of Fundy. They are probably the finest hay lands in the world. Some of them have been cropped 200 years. They are as sure to yield as the fields of Egypt.

By Man's agency in using the waters of the Nile for irrigation, Egypt became in olden time the granary of the world. Canals conveyed the water to lands not reached by the flood. And to-day the Egyptian peasant is using with profit the devices employed by his ancestors more than 3000 years ago. Sharply contrasted with these, as a result of modern engineering, is the great dam at Assuan by which an ample water supply, for irrigating purposes, has been afforded to a large territory. Much of the country yields three crops every year.

In India and Ceylon vast districts of country are rendered fertile by the use of reservoirs, constructed ages ago for collecting water in the rainy season, but even on a larger scale by the gigantic systems of irrigation constructed by the English.

The dry regions of our own country also are now largely irrigated. In Utah, California, Arizona, New Mexico, and other far Western states the wilderness has been, by this means, transformed into a garden. Some single "canals" with their distributing channels carry water to 150,000 acres.

Races of men, species of animals, and families of plants have been carried from one country to another, and their geographical range enlarged.

Indian corn, tobacco, and the potato, with many other plants, the turkey, and other animals, were indigenous to America. They have been carried to the Old World and acclimated. On the other hand, the horse and cow, the sheep, hog, goat, ass, and

other animals of the Old World, with wheat, oats, rye, barley, and rice, the sugar cane and coffee, and a great variety of other plants have been transported to America.

A few stray cattle and horses, escaping to the pampas and llanos of South America, multiplied exceedingly. So wonderfully did they increase that, upon the pampas, they were slaughtered by millions for their hides, horns, and tallow.

XXX. GEOGRAPHICAL DISTRIBUTION OF LABOR

Distribution of Labor Dependent on Physical Geography. — Every nation has industries peculiar to itself. These, to a large extent, have their root in geographical circumstance, or in difference of climate.

To show how human labor, when unaffected by tariffs and untrammeled by legislation, would naturally distribute itself over the earth in obedience to geographical law, let us suppose two families to have been planted originally on the earth, one at the equator, the other in the Arctic regions. How different, on account of their geographical surroundings, would be their occupations!

The intertropical family would seek the shades of the groves, pluck the ripe fruit overhead, require little clothing, and be exempt from undergoing the hardships of toil to earn their daily bread. With little exertion on their part nature would supply their wants.

The Arctic family, on the contrary, would be clothed with skins and furs; the earth would produce no grain or vegetables for them. They would live by the chase and the bounties of the sea.

Now, suppose these two families gradually to extend themselves, the one toward the north, the other toward the south, meeting midway near the isotherm of 50°.

The occupations of both, as they continued to approach this middle ground, would no longer be directed, on one side mainly toward the sea, and on the other exclusively to the soil; but would become more and more diversified.

The necessities of the southern family would compel them to resort to sundry active occupations, some to the manufacture of clothing, others to the fabrication of implements for husbandry;

others again to seafaring. Novel opportunities would present themselves to the northern community, and induce them likewise to subdivide their labor. They would divert a portion of it from the sea and the chase, and devote themselves to a greater or less extent to agriculture, to the forest, the mine, and the factory.

Such a diversity of occupation really exists among men. The middle latitudes, embracing regions lying not far from the isotherm of 50°, form a belt encircling the earth, where human occupations are most diversified. In some parts of this belt the tending of flocks and herds and the raising of stock are the chief industrial pursuits; in other parts agriculture, in others mining, manufacturing, seafaring, and lumbering; in some, all of these occupations, or several of them, are combined.

To the south of this middle ground, the attention of the people is devoted more and more to the field and the forest; to the north, more and more to hunting and the sea.

Along this middle ground are found the most active seafaring and commercial peoples in the world, the greatest manufacturing nations, and the largest cities.

Within its belt are included most of the United States, Japan, the populous parts of China, and all the great commercial, mining, and seafaring communities of Europe.

It is now easily perceived that there are geographical reasons why the people of South America, of Africa, India, and of the tropical and subtropical regions of the earth should, in the main, be agricultural or mining in their industries rather than seafaring or manufacturing.

In general it may be laid down as a rule, that the industries of every country are connected with its geography, and that human labor is distributed, largely, in obedience to certain physical conditions.

Industries of the United States. — A brief survey of the industries of our own country will serve well to illustrate this law of the geographical distribution of labor.

Let us observe in the first place how the principle applies to

our various agricultural pursuits. Climate, of course, furnishes the predominant reason why different products are raised in different parts of the country. But we shall notice that other minor causes are not without their influence. In the valley of the Mississippi, which may be regarded as the great agricultural region, there is found as we advance northward from Louisiana, a succession of climatic belts, and a corresponding variety of crops engaging the attention of the husbandman.

First of all, near the borders of the Gulf of Mexico, comes a belt in which sugar and rice are important crops. Leaving this belt, we enter regions, one after another, specially adapted to the cultivation of cotton, tobacco, corn and wheat, hemp, the grape, and orchard fruits.

If the journey lie along the Atlantic slope from Florida to Maine, we find a similar succession of belts and products; but with this striking difference, owing to the influence of the sea, namely, that the climates are milder and the belts broader.

In the "Tide-water Country" these belts are so widened that rice cultivation is carried up into North Carolina, cotton is raised in Virginia, and figs in Maryland — all much farther north than on the west of the Appalachians.

In the tide-water country of Georgia and the Carolinas, rice is an important article of cultivation. There is a geographical reason for this. Rice fields, in certain stages of the crop, must be flooded, for which purpose the tidal creeks and rivers of the seaboard afford excellent facilities.

At the same time Louisiana and Texas have become the leading rice-growing states of the Union. In the Mississippi delta the river is high above the cultivated ground. Consequently a supply of water can be obtained by simply tapping the river. In the southwestern parishes, away from the river, and on the coastal plain of Texas, large areas of low and level lands are irrigated from surface reservoirs and wells.

The agricultural pursuits of the Pacific slope, owing to its physical peculiarities, differ from those of the Atlantic. No rice or cotton is cultivated. But the region is unsurpassed for its

wheat and fruit crops; the olive, vine, and orange yield abundantly, while stock raising and wool growing are profitable employments.

Considering now the various other industrial pursuits of our people, we find it to be the rule that Physical Geography has largely determined how the occupants of each section shall employ themselves.

Here we view far-reaching grass-covered plains which naturally suggest the occupations of stock raising, dairying, or wool growing. Elsewhere we traverse forests famed for lumber, ship timber, and naval stores. In yet another region we observe that attention is directed to the great lakes or water courses for fish and fowl; or to the interior of the earth for minerals; or to commerce, manufacturing, and navigation.

All these occupations are, it is true, adopted according to individual fancy, yet they are clearly prompted and controlled by geographical influences.

Industries of New England and Gulf States Contrasted. — A very striking illustration of the law of geographical distribution of labor is obtained when we contrast the leading occupations of such widely separated sections of our country as the Gulf states and New England.

In the former there is no "wintry weather." The husbandman may labor in the field all the year long, and the soil yields abundantly.

In New England, on the other hand, the ground is covered with snow, or is frozen hard, during four or five months in the year. How is New England industry to ply its hand during this period? It cannot till; neither can it stand idle.

Forests upon the mountains, ships upon the sea, quarries of valuable stone, and above all factories of every description furnish ample employment for the industrious population. New England is preëminently devoted to manufacturing. Its polished granites and marbles are distributed everywhere along the Atlantic seaboard for building and ornamental purposes; its manufactures find a market in every part of our own country and are

exported to the far-distant seaports of China and Japan and the islands of the seas.

Louisiana, and her sister Southern states, on the other hand, want laborers for their harvests of cotton, corn, sugar, rice, naval stores, hemp, tobacco, etc. There are, therefore, inducements peculiar to each of these two sections which allure the people of one to this branch of industry, the people of the other to that, according to geographical conditions. In one, these inducements lead to the sea and the factory; in the other, they point to the bosom of the earth.

Mining and Manufacturing. — If coal and the useful metals are found in any region, manufacturing interests will sooner or later be developed. It is in no small degree owing to her vast deposits of coal and iron that Great Britain occupies her extraordinary position as a manufacturing nation. Pennsylvania, Ohio, Alabama, Illinois, the Virginias, Maryland, Michigan, and other states similarly rich in the useful minerals, are actively engaged in mining and metallurgy.

Fishing and Commerce. — Again, people are maritime in their habits from physical reasons; partly because they are adjacent to the sea, and partly because, owing to the conditions which surround them, the bounties of the sea are to them more enticing than the bounties of the land. Hence it is found that the seafaring populations of the world belong chiefly to those countries where, either from the poverty of the soil, the severity of the climate, or the high price of food, it is easier for some of the population to make a living by braving the sea than by delving on shore.

Ships at sea are not manned by sailors from the Mississippi Valley and the Southern states, where lands are cheap, climates mild, and where the soil is lavishly kind; but rather by men from New England, Great Britain, and the countries of northwestern Europe, where, largely on account of geographical conditions, the laborer finds it in many cases easier to make a living at sea than on shore.

Commerce originates between nations to satisfy needs. Articles required for food and shelter, comfort or luxury, being

irregularly distributed over the globe, it becomes necessary that human industry should be partly directed to the exchanging of the natural and artificial products of one region for those of another. To this end many routes of commerce have been established, necessitating the investment of great capital in railroads, steamships and other vessels, and at the same time giving employment to a vast multitude of people.

APPENDIX

XXXI. PHYSICAL GEOGRAPHY AS A SCIENCE

Scope of Physical Geography. — The earth is not young. Like a living being, it is a product of evolution or growth. In the course of its development it has passed through many stages. The interaction of sea and land, rock decay and denudation, transportation and deposition of sediment, vulcanicity and glaciation, elevation and subsidence, earth folding and faulting, animal and plant life, have all contributed to its present form. Yet the earth as we know it is not a finished product; change and remodeling are still taking place; the forces of the past, in varying degree, are still at work. It is, however, as the abode of man, chiefly, that the earth merits our attention. The relation of man to his environment or surroundings is a practical matter, and should we define Physical Geography as the study of the earth and its phenomena in the present stage of their existence with special reference to that relationship, we have before us a field of the widest scope.

The Relation of Physical Geography to Other Sciences. — It is only by a knowledge of the earth in its present condition that Man has been able to interpret its past history. Physical Geography is, therefore, a most important adjunct to geology. Indeed, there is no well-marked line of division between these sciences which, in many instances, occupy common ground. Geology, however, is usually confined to a consideration of the history of the earth and its inhabitants as recorded in the rocks. But this seems arbitrary in view of the fact that the earth is a unit. It were better that Physical Geography should constitute the latest chapter of geology.

Like geology, Physical Geography rests upon a foundation of other sciences. To explain the phenomena of the earth it has oftentimes been necessary to invoke assistance from astronomy, chemistry, physics, zoölogy, botany, and mineralogy; for the earth is one of the planets, it consists of matter, it is inhabited by animals and plants, and is, for the most part, composed of mineral substances.

How Physical Geography should be Studied. — In the elementary study of Physical Geography the text-book occupies an important position. Not only is such a work a record of the observations and conclusions of those who have made a specialty of earth phenomena, but also a manual of guidance for those who desire to acquaint themselves with the subject. Moreover, at the outset the student should understand that although the ability to memorize a text may add much to his information, it is by no means an index of his scientific attainments. If the best results are to be obtained from the study of Physical Geography, he should, as far as possible, verify the data and conclusions of the author. By training of that kind he may become competent to make independent observations and from them deduce proper conclusions. Then, and not till then, has he reached that degree of culture which is truly scientific. His local or home surroundings become now an ever-present field of research. Nowhere in the world is the opportunity for geographic investigation denied him. Lines of investigation open in many directions: He may observe winds, clouds, rainfall, temperature, and other weather conditions and note their bearing upon climate; he may study the effects of rock weathering or decay and the topographic features arising from erosion; he may face the problems of stream dissection, current action, delta formation, cascades and waterfalls in the rill formed by a passing shower; he may learn something of Nature's processes by observing the effects of storms and floods. These and many other fields of inquiry equally inviting lie within the reach of all students. Furthermore, every locality has its special phenomena: For example, wave action may

be studied by those living upon the sea coast or near lakes and ponds; ice action by those living in the colder regions of the earth; glaciers and glacial motion by those living in Alpine regions; and vulcanicity and earthquakes by those living in volcanic regions or parts of the earth subject to crustal disturbances.

Maps, Models, and Other Illustrative Materials. — There are, however, fields of geographic inquiry which ordinarily lie beyond the reach of most students, as the expense of investigation is too great or the region to be examined too remote or too inaccessible. To this class belong deep-sea research, electromagnetic observations, Arctic exploration, the investigation of high mountain ranges, the exploration of desert regions, and the like. Such forms of research can be carried on only under the auspices of the government or of well-endowed private institutions. The student of geographic tastes should embrace every opportunity to travel. There are problems worthy of his best thought and effort within the boundaries of his own state. But for the elementary student this also is usually impracticable, hence the necessity of a geographical collection in every school or college. This should include a set of the most recently published maps of the continents; a good atlas, selected folios, atlas sheets and charts from the publications of the United States Geological Survey and the United States Coast Survey; relief models of the continents; the Harvard Geographical Models; and a relief globe such as the Jones Model. In addition, if possible there should be included a set of lantern slides or photographic views. Such illustrations are extremely valuable to the student, as they convey to him an exact impression of the regions or phenomena under consideration. He should, moreover, have access to other books than the text, but their number will depend upon the resources of the individual or the school.

In higher institutions a similar equipment, but in an enlarged form, should constitute the furnishings of a geographic laboratory. Here the number of relief maps and models should be

greatly increased, especially by the addition of duplicates of the many excellent models prepared under the auspices of the United States Geological Survey and other departments of the national government. The collection of maps should also be made more complete, and embrace not only political, but topographic and geologic maps as well. If not found in other departments of the institution, some of the more common instruments for weather observation should be added, such as a mercurial or aneroid barometer, a themometer, a vane, anemometer, and rain gauge. This laboratory should be furnished with tables suitable for map work, cabinets for the storage of maps, photographs, and other geographic matter. While the facilities afforded by such a laboratory may increase many fold the value of Physical Geography as a study, they do not supplant the necessity of actual observation in the field.

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